Final Report

Mechanical Recycling of PVC Wastes

Study for DG XI of the European Commission

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1. Objectives and Work Programme

(1) **PVC** has been subject to a controversial debate amongst environmental groups (e.g. Greenpeace), governments, the public and industry for many years now. A number of environmental issues associated with the production, use and disposal of PVC have been addressed. In Europe, the debate has focused on a number of countries (Germany, Scandinavia, the Netherlands).

(2) A major reason of concern has been the disposal of **PVC wastes**. A number of environmental issues have been discussed. Additionally, PVC waste quantities are projected to increase significantly in the next years: A major part of PVC is used for long-life products in the construction sector (e.g. pipes, window frames, floor coverings) which are still in use. Since the large-scale consumption of PVC started in the 1970ies and taking into account the expected lifetime of 30 years and more, increasing amounts of these products will add to PVC wastes starting in the period 2000 - 2005. Also due to this effect present quantities are still comparatively small.

(3) Due to legal requirements which have been enforced to protect the environment, incineration and landfilling might be restricted in the next years. In some Member States **landfilling** of plastics wastes will even be **phased out**. To improve the overall environmental performance of PVC, **recycling** may be the most favourable future waste management option for PVC.

In some countries (e.g. UK, the Netherlands, France, Germany) the PVC industry has established recycling projects and recycling systems. The focus has been on mechanical recycling, but there are also projects for ”feedstock recycling”, e.g. incineration of PVC wastes with recovery of hydrochloric acid which can be used for PVC production and other applications.

However, up to now recycled waste quantities are low. The **costs** of recycling are high, thus considerable financial subsidisation is necessary to keep a price level that is competitive to the prices of landfilling and incineration. **Technical and environmental limits** to mechanical recycling are also known.

(4) This is the background for the recent efforts to develop an EU strategy for the management of PVC wastes. The Commission is committed to investigate the environmental issues associated with PVC wastes horizontally, as well as the need for policy measures at the EU level. Here, the evaluation of the **mechanical recycling of PVC** is a major issue, including an assessment of its advantages and limits and the identification of policy measures to improve it, if necessary and desirable. The arguments and conclusions published in the report reflect the authors' position and the Commission does not necessarily endorse every opinion and conclusion as stated in this report.

Objective of the Study

(5) The objective of the study is to assess the environmental, technical and economic aspects of the mechanical recycling of PVC and the evaluation of measures for improvements. In detail the objective includes the following aspects:

a) Quantitative and qualitative assessment of existing PVC waste recycling systems;

b) Identification of environmental, technical and economic problems involved in the recycling of PVC wastes;

c) Analysis of the impact of the presence of PVC on the recycling of other plastics;

d) Identification of Community and national measures to improve the recycling of PVC wastes.

Restriction to Mechanical Recycling and PVC

(6) Subject of this study is the mechanical recycling of PVC only. Mechanical recycling refers to recycling processes where the material is treated mechanically (e.g. grinding, seeving, screening). There exist other recovery and recycling processes, so called **"feedstock recycling"** processes like e.g. the controlled incineration with recovery of HCl which can be re-used for the production of chlorine (feedstock for PVC) or the so-called „Vinyloop" process which has been developed by the company Solvay recently. All these processes involve a chemical treatment of the PVC wastes. The incineration process includes a thermal decomposition and the „Vinyloop" process includes the dissolution of PVC wastes in a solvent with the subsequent recovery of pure PVC. As this study deals with mechanical processes only these processes are **not considered**. Nevertheless, they may provide additional potentials for the recovery of PVC wastes since they allow for the processing of PVC wastes with a comparatively high level of contaminations.

Furthermore it should be mentioned that this study deals with PVC only, even if some of the potentials and limits to PVC recycling are also true for the recycling of other plastics. This means that **neither the recycling of other plastics is assessed nor is the recycling of other plastics compared with the recycling of PVC**.

Work Programme

(7) An overview of the work programme is given in the figure below. The project is structured into seven working steps.

The description and assessment of existing recycling systems along with the collection and evaluation of data on the waste quantities in working steps 2 and 3 have constituted a major part of the study. A major part of the information has been obtained in interviews based upon a standard questionnaire (see annex). The interviews have been carried out on two levels:

- Interviews and discussions with the related European associations ECVM (European Council of Vinyl Manufacturers) and EuPC (European Association of Plastics Converters) which have delivered the basic data on present and future PVC waste arisings and recycled PVC quantities.
- Interviews with PVC industry, PVC and plastics converters, recycling organisations and recycling companies in the different Member States (Table 1.1).

Figure 1-1: Work Programme

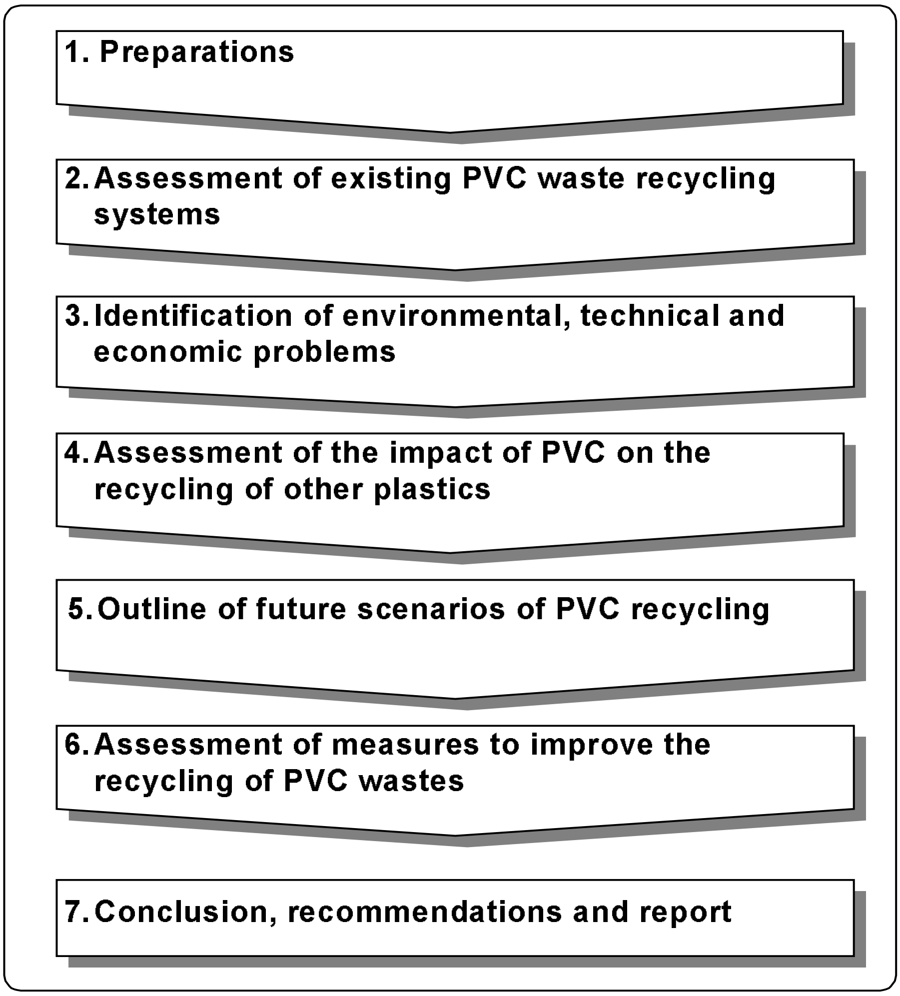


Table 1.1: List of Interviews carried out in the Member States (Selection)

EU Member State	Organisations interviewed
Austria	• A.P.I PVC & Umweltberatung GmbH, Wien • Österreichisches Kunststoffinstitut, Wien
Belgium/Luxembourg	• PVC Info, Brussels (PVC information council) • Rulo SA, Hérinnes-lez-Pecq (recycling)
Denmark	• PVC Informationrådet, Copenhagen (PVC information council) • WUPPI, Copenhagen (rigid PVC recycling) • NKT Cables A/S, Stenlille (cables manufacturer)
France	• Syndicat des Manufactureurs des Matières Plastiques (association of plastic manufacturers), Paris-la-Défense • Valorplast, Puteaux (bottle recycling)
Finland	• Finnish Association of Plastics Industry • Finnish Plastics' Recycling Oy • Ekokem Oy, (HWM company owned by the Confederation of Finnish Industries and the Finnish State) • Finnish Environment Institute, (national research institute)
Germany	• Arbeitsgemeinschaft PVC und Umwelt, Bonn • VEKA Umwelttechnik, Behringen (window recycling) • Kunststoffrohrverband, Bonn (plastics pipes) • Replast GmbH, Westeregeln (plastics pipe recycling) • R Plus GmbH, Eppingen (cable recycling) • Be Ha Rec, Castrop-Rauxel (cable insulation wastes trading)
Greece	• E. Beligiannis, Thessaloniki (PVC compound producer) • Hellenic Petroleum, Athens (PVC producer) • HE.R.R.A. - Hellenic Recovery and Recycling Association • Petzetakis A.G. SA, Athens (pipes manufacturer) • PlastiKO ltd, Papagou (bottle recycling)
Italy	• REPLASTIC, Milano (bottles) • Centro di Informazione sul PVC; Milano • Unionplast, Milano • RIMAPLAST, Mirandola (agricultural films recycling) • Silvyplast S.r.l.; Bernate Ticino (PVC sraps recycling, pre-consumer) • Tecnometal S.r.l., Bedizzole (cable recycling) • Sovere, Verona (PVC scraps recycling, pre-consumer)
Ireland	• PIA - Plastic Industries Association, Dublin
The Netherlands	• PVC Steering Committee Netherlands, Leidschendam • FKS - Vereniging Fabrikanten Kunststof Leidingsystemen, • Nedek / Draka Nederland, Amsterdam (cables)
Portugal	• CIRES (Companhia Industrial de Resinas Sinteticas), Estarreja (PVC producer)

EU Member State	Organisations interviewed
Spain	• ELF-ATOCHEM, Barcelona (PVC producer) • CICLOPLAST, Madrid (Packaging reclaiming • Hispavic Industrial S.A. (Solvay), Barcelona (PVC producer)
Sweden	• PVC Forum, Stockholm (PVC information council) • SWECO International, Stockholm (Consultants)
United Kingdom	• BPF – British Plastic Federation, London • Phoenix Rubber Ltd., Shropshire (cable insulation recycling)

2. Development of PVC Wastes – General Considerations

In order to assess the mechanical recycling of PVC, it is necessary to distinguish between the different PVC products and waste types respectively. The opportunities and limits of recycling are different depending on the product group. In order to develop a realistic future scenario of PVC recycling, it is also necessary to have a general knowledge of the major factors influencing the recycling quantities.

2.1 Classification of PVC wastes

(1) Like for other plastics, the recycling potentials of PVC are to a large extent determined by the degree of contamination which must be accepted for the collected wastes. **The production of high-quality recyclates is the easier the purer the collected PVC material is**. "Degree of contamination" refers to two criteria:

– the degree to which PVC is mixed with other materials when collected and

– differences in the composition of the collected PVC material itself.

As for the second aspect, it has to be taken into account that the PVC used in products does not consist of pure PVC but of PVC compounds which contain different quantities of additives, such as softeners, filling agents, stabilizers and others. One major difference in the material composition exist between rigid PVC applications with lower additive contents and soft PVC applications which may contain more than 50% of additives. Even in the same application (e.g. window profiles, pipes, films) the composition of the PVC material differs between different PVC converters having their own specific PVC compounds and between different production years, due to technological advances. For example, in cable insulations the content of additives (plasticisers, fillers, stabilisers) ranges from 50 – 60% with different mixtures and compounds being used.

The production of high-quality recyclates with defined technical specifications (e.g. strength, elasticity, colour) requires input materials with a defined quality, i.e. pure PVC in terms of the contents of other materials and composition of the PVC compounds.

(2) The degree of contamination which can be achieved for collected PVC wastes depends to a large extent on

– the type of waste in which the PVC products end up and

– the PVC application (product group).

Therefore, in this study PVC wastes will be classified depending on these criteria (Table 2.1).

Table 2.1: Classification of PVC wastes (I)

PVC Applications[a)]	PVC Waste types (X = existing or possible)					
	Pre-consumer Wastes		**Post-consumer Wastes**			
	Pro-duction Wastes	Instal-lation Wastes	PVC "Mono Fractions"[b)]		Composite Products/Materials	
			Separate Collection	Mixed Collection	Separate Collection	Mixed Collection
1. Construction products						
• Cables (F)	X	X			X	X
• Flexible films (F)	X					X
• Flooring calandered (F)	X	X	X	X		
• Flooring paste (F)	X	X			X	X
• Roofing membranes (F)	X	X			X	X
• Profiles and hoses (F)	X	X		X		X
• PVC wall papers (F)	X	X				X
• Air inflated structures, container, marquee (F)	X					X
• Varnishes–coil coating (F)	X					X
• Pipes (R)	X	X	X	X		
• Window profiles (R)	X	X			X	X
• Profiles – cable trays (R)	X	X	X	X		
• Other profiles (R)	X	X	X	X		
• Pipe insulation films (R)	X					X
• Sheets (R)	X	X		X		
2. Packaging products						
• Flexible films (F)	X	X		X		X
• Cans (F)	X					X
• Rigid films (R)	X	X		X		X
• Bottles (R)	X		X	X		
3. Furniture components						
• Flexible films (F)	X	X				X
• Flexible profiles (F)	X	X				X
• Rigid films, kitchens (R)	X	X				X
• Rigid films, drawers (R)	X	X				X
• Other rigid films (R)	X	X				X

Table 2.1: Classification of PVC wastes (II)

PVC Applications[a]	PVC Waste types (X = existing or possible)					
	Pre-consumer Wastes		Post-consumer Wastes			
	Pro-duction Wastes	Instal-lation Wastes	PVC "Mono Fractions"		Composite Products/Materials	
			Separate Collection	Mixed Collection	Separate Collection	Mixed Collection
4. Other consumer and commercial products						
Bags, luggage, cushions (F)	X				X	X
Office supply, books, photo articles (F)	X				X	X
Camping, leisure, toys (F)	X			X		X
Misc. plasticised films (F)	X					X
Garden hoses (F)	X			X		
Drinking hoses (F)	X			X		
Other industrial hoses (F)	X			X		
Other flexible profiles (F)	X	X		X		X
Artificial leather (F)	X	X				X
Conveyor belts (F)	X					X
Miscellaneous coatings (F)	X	X				
Rotational mouldings (F)	X					X
Slush mouldings (F)	X					X
Misc. organo-/plastisols (F)	X					
Shoes, soles (F)	X				X	X
Miscellaneous (F)	X					X
Office supply (R)	X		(X)	X	X	X
Printing films (R)	X		(X)	X		
Credit cards (R)	X			X		
Computer disks (R)	X			X		
Other techn. applications (R)	X			(X)		X
Sheets, chemical equipm. (R)	X	X	(X)	X		
Miscell. sheet products (R)	X	X		X		
Miscell. rigid profiles (R)	X	X		(X)		X
Vinyl records (R)	X			X		
Other rigid products (R)	X			(X)		X
5. Electric/electronics						
• Cables (F)	X	X			X	X
• Adhesive tapes (F)	X	X			X	X
• Flex. profiles, hoses (F)	X	X			X	X
• Inject. moulding parts (F)	X	X			X	X
• Rigid profiles	X	X			X	X

Table 2.1: Classification of PVC wastes (III)

PVC Applications[a)]	PVC Waste types (X = existing or possible)					
	Pre-consumer Wastes		**Post-consumer Wastes**			
	Production Wastes	Installation Wastes	PVC "Mono Fractions"		Composite Products/Materials	
			Separate Collection	Mixed Collection	Separate Collection	Mixed Collection
6. Automotive						
• Cars cables (F)	X	X			X	X
• Instrument panels and other films (F)	X	X				X
• Cabletapes and cable-binders (F)	X	X				X
• Hoses, flexible profiles (F)	X	X				X
• Foamed films/artificial leather (F)	X	X				X
• Tarpaulins for lorries (F)	X	X			X	X
• Underfloor protection (F)	X					
• Others, inj. moulding (F)	X					X
• Rigid profiles (R)	X	X	X	X	X	X
• Battery separators (R)	X				X	X
7. Other Products						
• Agricultural films (F)	X		X	X		
• Medical products (F):	X	X	X	X	X	X

a) F = Flexible PVC applications; R = Rigid PVC applications

b) Only those type of wastes are taken into consideration for PVC mono fractions where the potential collection quantities (in separate collections) or the PVC content of the mixed waste streams (in mixed collections) are big enough. Details are discussed in Chapter 4.

(3) With regard to the PVC **waste types** two major groups must be distinguished:

1.) **Pre-consumer wastes** are generated in the production of PVC final and intermediate products (**production wastes**) and **installation wastes** from the handling or installation of PVC products: The processing of PVC to final products takes one to more than three production steps, each of them may be carried out by a different company. For example, the production of packagings starts with the production of films from PVC compounds in calanders followed by the thermoforming of the films to packagings in a second step. In each step production wastes are generated (e.g. cut-offs in the calandering of films). Some of the final products have to be handled or installed to reach their final purpose, resulting in additional installation wastes. Cut-offs from the laying of cables or floorings are examples. A part of the pre-consumer wastes is recycled at the PVC processors in-house (production wastes like the cut-offs from the production of films can be used directly as raw material in the same process), the other part is collected by recyclers. The collection of installation wastes especially is carried out by recycling companies which return the material to the PVC processors after mechanical treatment. PVC pre-consumer wastes as a group are comparatively easy to recycle, since they can be collected separately in defined qualities. This is why recycling of PVC pre-consumer wastes is applied to a large extent in practice.

2.) The recycling of **post-consumer wastes** is generally more difficult to realize since they occur in form of products (end-of life products such as pipes, windows, packagings) and hence in more or less mixed waste fractions or as a part of composite materials. Depending on the specific products, PVC in wastes can occur as a more or less pure material fraction (in **"mono fractions"**) which can be extracted from the waste stream by sorting (e.g. bottles, pipes, some films, some profiles). Alternatively, PVC can form a part of **composite products or materials** which must be subjected to disassembling or mechanical treatment processes in order to extract PVC (e.g. windows, car components, floorings, cables). Both PVC "mono fractions" and composite products/ materials can be collected separately (i.e. in product specific collection systems, e.g. bottle, window or cable collection systems) or in mixed fractions together with other materials (e.g. packaging wastes, municipal solid wastes).

(4) For the post-consumer wastes the different **PVC product groups** determine to some extent in which specific waste flow the PVC occurs. It is also the waste flow (not the material as such) which determines how easy or difficult PVC can be separated out as a pure fraction. And it is only the waste flow which can be influenced by waste management measures and policies.[1] We distinguish five different product groups:

– construction products (pipes, windows, flooring, etc.) which end up in construction and demolition wastes – many products arrive at mixed waste streams today but a separate collection is feasible, a part of it even as "mono fractions" (pipes and some profiles);
– consumer and technical products (packagings, rigid film applications, etc.) arrive at (mixed) municipal solid wastes (from households, industry and commerce) or (mixed) packaging wastes; a separate collection is feasible for few products only;
– vehicle components (e.g. dashboard elements, cables, coatings) which unless dissambled before shredding end up in the shredder residues;
– electric/electronic products forming the so-called electro/electronics waste whose major share arrives at municipal solid wastes, but a separate collection is feasible;
– other products ending up in special waste flows (e.g. hospital and agricultural wastes).

1) This has been taken into account for example by the Priority Waste Stream Projects of the European Commission.

2.2 Factors influencing PVC recycling

2.2.1 Overview

(1) In order to analyse, to forecast and to improve the mechanical recycling of PVC it is necessary to have a general knowledge of the factors which determine the recycled quantities.

The absolute quantity of recycled PVC per year can be thought as a result of

- the total annual quantity of PVC in wastes
- and the recycled fraction of it (”recycling rate”).

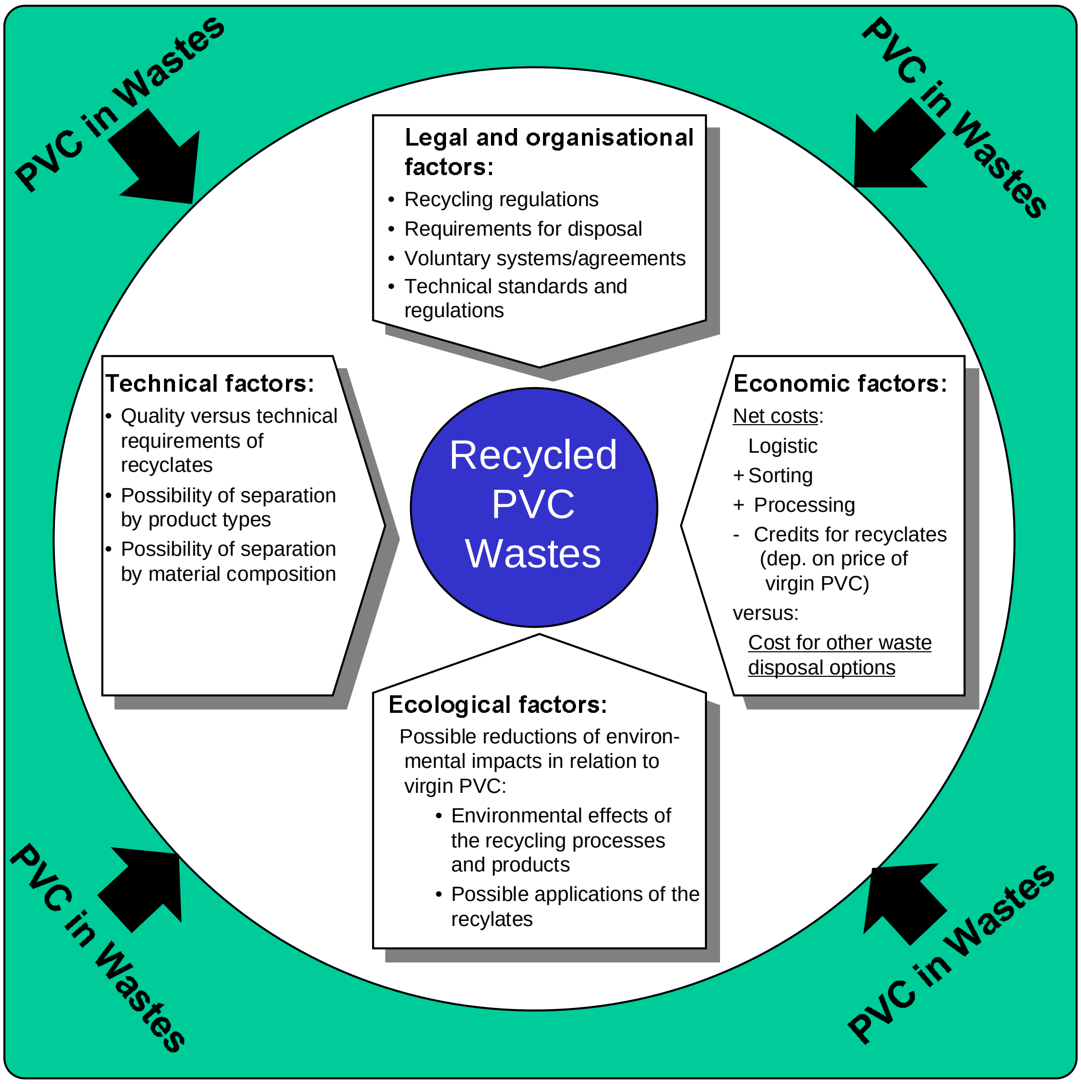
(2) The **total quantity of PVC in wastes** is a function of PVC consumption: The higher the PVC consumption the higher will be the quantity of PVC in wastes. In contrast to most other commodity plastics, (especially polyethylene and polypropylene) the major part of PVC production is converted into long-life products in the construction sector (pipes, windows, etc.) with an expected life-time of up to 50 years and more. This is why there is a considerable **”time lag” between PVC consumption and PVC in wastes**: The PVC production consumption took off to reach significant market shares in the 1970s. The production quantities of many large volume products such as window profiles reached an order of magnitude near today's production levels not before the beginning of the 1980s. So, with an average lifetime of around 30 years for PVC products as a rule of thumb, the quantity of PVC in wastes is still very small compared to PVC consumption. The ”big push” of PVC waste quantities can be expected to start around 2010 only.

The total waste arising of PVC has an impact on PVC recycling not only because it determines the absolute amounts of recyclable PVC but also due to the fact that the feasibility of a **recycling system requires a minimum quantity of wastes**. This is due to the fact that recycling plants must reach a minimum capacity to allow for a technical and economic feasible operation. Also the geographical area supplying one recycling plant must not exceed a certain size in order to keep transport distances and costs in a reasonable range. Additionally, the PVC content in mixed wastes must be high enough to make the operation of separate collection system or specific separation and sorting processes feasible.

(3) The part of total PVC wastes which is going to **recycling** (”recycling rate”) depends on four major factors (Figure 2-1):

- Technical factors, mainly the achievable quality of the recyclates in relation to the required quality in the possible applications; this is in turn determined by the degree of contamination of the collected PVC wastes or the relevant waste streams respectively;

Figure 2-1: Factors influencing recycled PVC waste quantities



- Legal and organisational factors, including recycling regulations (e.g. minimum recycling quota), statutory requirements limiting or discouraging the use of the "non-recycling" waste disposal routes (especially landfilling and incineration), voluntary agreements or commitments of industry to establish (and finance) collection and recycling systems and finally technical standards and regulations limiting the application of the recyclates (e.g. certification systems, food contact laws);

- Economic factors, especially the overall (net-)cost of recycling (collection + logistic + sorting + treatment - credits for produced recyclates), which is inter aliam influenced by the price of virgin PVC and the technical factors (degree of contamination);

- Ecological factors, especially the achievable savings of resources and emissions to the environment due to the substitution of virgin PVC and other materials in relation to emissions and resource consumption of the recycling processes (collection, transport, treatment/processing, etc.); the achievable savings depend on the products/materials which can be substituted by the recyclates, which in turn depends on the achievable quality of the recyclates (i.e. high-quality recyclates can substitute virgin PVC, low-quality recyclates or mixed plastics recyclates can substitute concrete, wood or other non-plastics only).

It must be pointed out that there is a **close connection between the different factors**. Especially, the economic and environmental performance of PVC recycling is closely linked to the technical factors (degree of contamination, separate collection, etc.). Therefore, for the assessment of PVC recycling the whole picture must be taken into account.

2.2.2 General Analysis of the Impact of the Factors Influencing PVC Recycling

(1) At this stage a general analysis of the impact of the different factors described above will be given. A more specific analysis has been elaborated in the description of the existing PVC recycling systems taking also into account country-specific circumstances (Chapter 3).

TECHNICAL FACTORS

(2) The technical potentials of the mechanical PVC recycling are determined by the **achievable quality of the PVC recyclates**. To be used for the production of new products, recyclates must comply with a set of technical specifications which at last refer to the contamination and the composition of the recyclates.

These specifications take account of the specific characteristic of PVC that the composition of the material differs depending on the specific application:

– Much more than other commodity plastics - such as polyethylene and polypropylene - PVC is a compound material, i.e. it does not consist of polymer PVC alone but includes also a variety of additives such as stabilizers (to avoid degradation of the PVC), plasticizers (in flexible PVC), fillers, impact modifiers, pigments and processing agents.

– Each PVC application has its specific material composition (Table 2.2).

– Also for a specific PVC application, the composition of the PVC compounds can differ depending on the producer or processor. Furthermore, the composition of the PVC compounds for a specific application has changed in time due to technological changes, e.g. today window profiles are produced from different PVC compounds than window profiles 20 years ago.

Table 2.2: Typical composition of PVC compounds (Prognos 1994, Prognos 1999; Tötsch 1990)

Application	Share of the components (weight-%)				
	PVC polymer	Plasticizer	Stabilizer	Filler	Others
Rigid PVC applications					
Pipes	98	–	1-2	–	–
Window profiles (lead stabilised)	85	–	3	4	8
Other profiles	90	–	3	6	1
Rigid films	95	–	–	–	5
Flexible PVC applications					
Cable insulation	42	23	2	33	–
Flooring (calander)	42	15	2	41	0
Flooring (paste, upper layer)	65	32	1	-	2
Flooring (paste, inside material)	35	25	1	40	-
Synthetic leather	53	40	1	5	1
Furniture films	75	10	2	5	8
Leisure articles	60	30	2	5	3

Therefore, even by separate collection of PVC wastes by type of product it is hardly possible to gain PVC material of an exactly uniform composition. For pre-consumer wastes it may be possible to recover material of a defined composition (if for example a cable layer returns cut-offs to his specific supplier). This is however not the case for post-consumer wastes.

– As a consequence, **at least for post-consumer wastes, a 1:1 substitution of virgin PVC by recycled PVC is not feasible.**

Nevertheless, in some applications like window frames PVC wastes of different compositions can be mixed in practice and recycled as separate material layers.

The quality of the recyclates is determined by the degree of contamination and the variation of the composition of the collected material. We distinguish between two major groups of recyclates:

- **"High-quality recyclates"** from a specific PVC application can be re-used in the same application due to their low degree of contamination and similar composition. Due to the differences in the composition of the PVC compounds, the recycling material can be used as a separate layer in the new products (e.g. core of window profiles, medium layer in pipes) in most cases. One problem is that the recycled products are of different colours, so the recycling process must provide for a separation by colour or the collection must be separated by colour which in many cases is not feasible in practice. As a minimum requirement for high-quality-recyclates, soft PVC recyclates cannot be used in rigid PVC applications. Also recyclates from rigid PVC products are generally not applied for soft PVC applications since the material has to be reformulated, i.e. plasticizers and other additives have to be added. An exchange of material inside each group, soft and rigid PVC applications, is feasible to a limited extent.

- If these requirements cannot be met by the recycling system, **"low-quality recyclates"** are produced which due to a higher degree of contamination and a mixture of PVC material from different applications cannot be used but as a substitute for "non-PVC-materials" only (e.g. general plastics, concrete or wood products). This type of recycling is generally referred to as **"down-cycling"**.

The assessment of the existing PVC recycling activities will show which quality is achieved for the recyclates in practice (see Chapters 3.3 and 4.1).

It should be mentioned that the quality issue of the recyclates is only partially specific to PVC. It applies also for the recycling of other plastics, where the collection and separation of pure fractions is the major bottleneck.

(3) The achievable quality of the recyclates depends greatly on the **achievable degree of contamination of the collected PVC wastes**. In order to produce high-quality recyclates it is necessary to have the PVC wastes collected by type of application (pipes, windows, floorings, etc.). With this in mind, the recycling potentials of PVC wastes can be roughly classified as follows (Figure 2-2):

- The highest-quality PVC recyclates can be achieved from PVC **production wastes**: The wastes occur at PVC converters where PVC wastes of defined compositions (i.e. additive contents) are produced which can be used nearly as an equivalent to virgin PVC;

- The (technical) recycling potential of **cut-off wastes** from the handling or installation of the different PVC products is also high. However, depending on the product, logistic conditions and the collection of PVC charges with specified compositions are more difficult than for production wastes, due to a disperse distribution of the "waste producers" (e.g. large number of small workshops or enterprises producing windows or laying floorings).

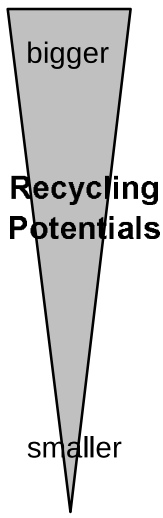
- The technical recycling potential of post-consumer wastes is generally lower than the recycling potential of pre-consumer wastes since the collection of fractions with defined material compositions is not feasible in most PVC applications. Thus lower-quality recyclates are produced or expensive sorting or separation processes have to be applied. The highest recycling potentials of PVC post-consumer wastes can be expected for **”mono fractions” which can be collected separately**. This applies for pipes, (rigid) profiles, bottles, a smaller part of rigid film applications, some car components (which can be disassembled) agricultural films and some medical products.

- Moderate recycling potentials can be attributed to **PVC-”mono fractions” in mixed wastes** (e.g. profiles or pipes in mixed construction wastes, packaging films in mixed packaging wastes) and **composite materials which can be collected separately** (e.g. windows and cables). In order to gain higher-quality recycling materials the first group of PVC wastes must undergo a sorting process to extract PVC, whilst the second group of PVC wastes must be treated in a mechanical separation process to separate PVC from the other materials in the related products.

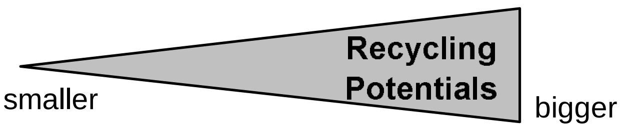
- PVC in **composite products which cannot be collected separately** have the lowest recycling potentials. In many cases a mechanical recycling is not feasible at all, in some cases a recycling in mixed plastics fractions may be possible yielding low-quality materials with a limited application spectrum (**”down-cycling”**).

Figure 2-2: General Technical Recycling Potentials of PVC Wastes

	Purity of PVC recyclates	
	PVC fraction of a homogenous composition	mix of different PVC compounds
1. Pre-consumer Wastes		
a.) Production Wastes	✓	✓
b.) Cut-offs	(✓)	✓
2. Post-consumer Wastes		
a.) PVC ”Mono Fractions”		
• Separate Collection	–	✓
• Mixed Collection	–	(✓)
b.) Composite Products		
• Separate Collection	–	(✓)
• Mixed Collection	–	–



✓ = possible
(✓) = limited
– = not possible



It must be taken into account that with **recovery processes other than mechanical recycling** the potentials to recover composite products and materials from mixed collections may be increased significantly. Such processes include e.g. the "Vinyloop" process which is based upon the dissolution of PVC wastes in a solvent, allowing for the processing of commingled PVC wastes to obtain comparatively pure PVC recyclates. All these processes are based upon chemical operations and are thus not included in the scope of this study (see Chapter 1).

LEGAL AND ORGANISATIONAL FACTORS

(3) The **EU legal framework** is particularly important for recycling. As a matter of fact, recycling is in most cases not a profitable operation (this will be dicussed in more detail in Chapters 3.2 and 3.3). Therefore, in order to make use of the environmental advantages of recycling it is necessary to enforce or encourage recycling by legal regulations.

In the particular case of the recycling of PVC, several regulations have to be respected. The legal framework may involve several administrative levels. Most of the issues concerning recycling and waste management have been dealt with at the Community level. The directives and decrees define the general principles and the targets to be achieved. The Member States must provide for the laws allowing to attain these goals. In some cases (especially in Belgium, but also in the UK and Germany), the regions are responsible for making environmental laws.

It has to be pointed out there is no PVC-specific waste regulation in the EU. However, PVC as well as other plastics are concerned by two types of regulations:

- regulations putting requirements on incineration and landfilling and thus encouraging or enforcing recycling;
- product-specific or waste stream-specific regulations (vehicles, electronic equipment, etc.) laying down recycling targets.

(4) In order to fix the general targets and needs for action to reduce, recover and recycle wastes the Commission has carried out **Priority Waste Streams Programmes** for several specific waste streams. Of particular relevance for PVC has been the programme on construction and demolition wastes. However, no specific Community regulations have resulted from this activity by now.

(5) Specific regulations on the EU level are as follows:

– **Directive on the Landfilling of Waste:**
The Landfilling Directive which was adopted in April 1999 defines standards for construction and management of landfill sites as well as requirements for landfilled

wastes.

It can be expected that the implementation of the directive will result in increasing landfill costs, thus possibly encouraging recycling. This is due to the technical requirements concerning isolation measures and effluents captation, the stipulation that the prices charged for waste disposal have to reflect the real costs for the whole lifetime of the landfill site (including costs for protection measures after the shut down of the site) and finally that the directive allows for economic instruments such as taxes on wastes to reduce landfilling.

Furthermore the directive stipulates that wastes shall be pre-treated prior to their landfilling and includes reduction targets for the landfill of biodegradable wastes. However, many EU countries have already fixed **national regulations** which are more stringent in this respect. For example in France, the Netherlands, Austria and Germany direct landfilling of reactive wastes, including also plastics, shall be phased out before 2005. These regulations may encourage plastics recycling since there remain incineration or under certain conditions biological treatment as final disposal options for plastics wastes only, involving higher costs than landfilling. However, due to the comparatively high level of recycling costs (see Chapter 3.3 below) the cost increase must be significant to make recycling economically competitive to incineration and other disposal options. Furthermore, in the other countries which are going to implement the EU Directive without major modifications landfilling is expected to remain an important waste management option in the foreseeable future.

– **Draft Directive on the Incineration of Hazardous and Non-Hazardous Waste:**
  In 1997 the Commission adopted a formal proposal for a Directive on Non-Hazardous Waste Incineration. It will apply harmonised rules to co-incineration and MSW incineration including also emission limits such as for dioxins and furans and heavy metals (Cd, Pb, Hg). It can be expected that these requirements will increase the cost for incineration and discourage the co-incineration in cement kilns and other industrial combustion facilities. Therefore, like the landfill directive, this directive may encourage PVC recycling depending on the extent of the cost effects.

– **End-of-life vehicles (ELV):**
  The Commission's proposal for a Directive on End-of-life Vehicles incorporates recycling targets. By 2015, 95% by weight per vehicle shall be reused and recovered where recycling should reach a rate of 85%. For the time being, only the metal fraction (75% by weight) is being recovered. The recycling targets of the proposed Directive imply that also the non-metallic shredder residues must be recovered. In order to achieve these goals, a number of framework measures have been included such as the promotion of European standards relating to dismantling, recovery and recycling of vehicles, the identification and marking of components and materials; the establishment of systems for the collection of all end-of-life vehicles where the last holder can discard his vehicle free of charge. Also the use of hazardous substances (such as heavy metals) in the vehicles and in the related waste flows going to shredder plants, landfills or incineration shall be reduced. In this connection, a former draft of the Directive included also a **ban of PVC** to prevent the formation of toxic substances

such as dioxins in the recycling processes (especially in the metal industry using the recycled materials). In the latest draft of the Directive, this passage has been removed and in the counter-move the so-called ”horizontal studies” have been initiated to assess the waste management of PVC ”horizontally” for all relevant PVC applications. This study is a part of it.

Also on the **national levels** a number of agreements, initiatives and regulations has been created. They include minimum recovery and recycling targets or maximum land-fill targets which coincide with the targets set by the EU in most cases. In many countries, voluntary agreements have been signed. In some cases plastic recycling goals have been set (in Belgium, a 30% target is under discussion). In France, a recycling system for PVC in ELV has been established by industry in 1997, in the frame of the voluntary “Autovinyle“ programme. A variety of financing models have been elaborated, including a dismantling fee to be paid by the last user, insurance models (all car owners pay a monthly sum), and a levy to be paid when purchasing a new car. For the time being, it is not clear as to whether these regulations will encourage the mechanical recycling of PVC or not. This will depend on the technologies applied to achieve the recovery goals. Some quantities of PVC may be recovered for mechanical recycling by dismantling of the end-of-life vehicles prior to shreddering. However, a large share of PVC will still be included in the shredder residues. For the time being, it is not clear which treatment processes will be installed for the shredder residues, but a mechanical recycling process with separation of PVC seems to be unlikely.

– **Draft Directive on Electric and Electronic Equipment:**

The draft proposal for a Directive on Electric and Electronic Equipment (EEE) aims at preventing waste from EEE, encouraging recovery and minimising risks associated with the treatment and disposal of end-of-life EEE.

Take-back systems for EEE wastes shall be set up whose costs (collection, treatment and recovery) shall be borne by the producers. The target for separate collection is 4 kg per inhabitant per year of EEE from households. For the collected wastes recycling targets have been stipulated, depending on the appliances (90% by weight for large household appliances such as refrigerators or washing machines, 70% for small household appliances, IT, audio and video equipment).

The Member States shall encourage manufacturers and importers to minimise the use of dangerous substances (such as lead, cadmium, chromium and halogenated flame retardants) as well as the number of different plastics, promote design for reuse and recycling and ensure that manufacturers and importers use common component and material coding standards. Also to reduce risks from hazardous substances a pre-treatment of the wastes is required.

In some Member States voluntary agreements with industry or national laws have been implemented. The solutions which have been proposed are similar to those established for EOL vehicles. In most cases, EEE can be returned to certified recyclers free of charge, provided a similar item is purchased. In certain countries, the recycling is financed by a levy for new appliances or a disposal fee has to be paid. Pilot projects on mobile phone recycling have been set up in Sweden, the UK and Spain. They are expected to reach a national coverage in future.

The existing practice of EEE recycling is to apply mechanical treatment processes to separate the different components of the EEE wastes. In most cases PVC constitutes a component of a mixed plastics fraction which can be recycled mechanically (to a low-quality material) but also landfilled, incinerated or recovered in thermal processes. Hence, it seems to be unlikely that these regulations will result in a drastic increase of mechanical PVC recycling.

– **Packaging Directive:**

The Packaging Directive (94/62/EC) of 1994 sets harmonized requirements for the recycling of packaging wastes. The Directive stipulates that no later than 2001 more than 50% (but less than 65%) by weight of the packaging waste have to be recovered and more than 25% (but less than 45%) have to be recycled. Additionally, at least 15% of each individual packaging material must be recycled. These targets will be reviewed and can be revised before 2006. National programmes going beyond these targets have been permitted (e.g. in Germany and Austria) and Greece, Ireland and Portugal have been allowed to adopt lower standards (the decision has to be taken no later than 2001), but should reach at least 25% for recovery.

To ensure the achievement of these targets return, collection and recovery systems must be set up in the Member States. The Directive stipulates also that packagings must comply with so-called „essential requirements“ concerning design and composition (e.g. minimisation of weight, the packaging design must support recovery and recycling, minimisation of hazardous materials) and defines standards for heavy metals in packagings. Additionally, the Directive includes several information and reporting requirements and processes.

The Directive has been preceded by ordinances in other countries (e.g. Germany, Austria) and has been inspired by them. All Member States have adopted or are adopting systems for collection, sorting and valorisation for the packaging waste.

The Directive has been increasing the recycling of PVC used in packaging applications. In some countries like France, PVC bottles are collected and recycled separately. The major part of the other PVC packaging applications is collected and sorted in mixed plastics fractions, which are recycled mechanically to a limited extent only, producing low-quality recyclates which substitute non-plastic materials like concrete. A major part of the mixed plastics fraction is recovered in thermal processes, feedstock recycling processes, or it is incinerated.

– **PCB and PCT:**

The Directive 96/59/EC of 16 September 1996 on the disposal of PCB and PCT defines the requirements and conditions for the collection, marking and phase-out of PCB and PCT and materials containing PCB and PCT. In accordance with this directive "PCB" means also any mixture containig PCB/PCT in a total quantity of more than 0.005% by weight, i.e. 50 mg/kg.

This Directive has been implemented or will be soon transposed in national law. It has some relevance for the recycling of electric cables, since it has been experienced that the recovered plastics fraction can contain limited concentrations of PCB.

In Germany a working group of the Government and Federal States has proposed to reduce the maximum tolerable PCB content of materials to 5 ppm. In the Netherlands, a limit of 1.5 mg/kg PCB has been set in order to protect the North Sea.

– **Construction and demolition wastes:**
Since PVC is mainly used to produce building materials, regulations on construction and demolition waste are of special relevance. However, there is currently no specific EU legislation for this waste stream.
In most countries, construction and demolition wastes have not to be collected separately nor recycled. Only in some Northern European related regulations exist. In Sweden, a voluntary agreement has been signed aimed at reducing the construction wastes to be landfilled by 50% by the year 2000. In Germany, recycling and selective collection are being done in some municipalities. The Netherlands have achieved a recovery rate of 80-90% by banning the landfilling of construction wastes.

– **Agricultural plastic wastes:**
This wastes have not been regulated at EU level. In Ireland, where this waste stream is relatively important, a recovery obligation (similar to the one existing for packaging waste) has been established.

(6) The following table sums up the relevant legislation and agreements in the Member States.

Up to now, legal requirements have not encouraged PVC recycling significantly. So far, they have influenced the packaging sector only. Apart from legal requirements some PVC recycling has been encouraged by **voluntary recycling systems** established by industry. These include inter aliam the recycling of pipes in the Netherlands, windows, pipes, floorings and roofing in Germany, the recycling of construction and demolition wastes containing also PVC in Denmark, the recycling of computer casings in the UK or the recycling of PVC components in end-of-life vehicles in France ("Autovinyle" programme).

Further information on the situation in the Member States is given below (Chapter 3.2).

(7) **Technical standards** may limit the application of PVC recyclates. Although it is not possible to establish a comprehensive overview of the relevant standards the situation in partial areas allows for the conclusion that this is indeed a relevant factor in practice: Nearly in the whole pipe sector which is the major PVC application the relevant European Standards have not allowed the use of recyclates by now (ISI 1998). Only in few single pipe products recycled materials can be used (in Germany e.g. drainage pipes for landfills). Similar restrictions apply in the food sector (PVC application: films, bottles), where only materials with a defined and known composition can be used for food containers and packagings according to the related food regulations. Generally this cannot be guaranteed for plastics recyclates.

Table 2.3: National Environmental Legislation and Agreements - Overview

Country	Legislation				
	Packaging	**EOL vehicles**	**EEE**	**PCB**	**Construction wastes**
Austria	Nat. Leg.[a)]	Vol. Agr.	Nat. Leg.	EU	Pilot Proj.
Belgium	EU	Nat. Leg.[b)]	Nat. Leg.	EU	---
Denmark	EU	(Nat. Leg.)[c)]	Nat. Leg.[e)]	EU	Vol. Agr.
France	EU	Vol. Agr.	–	EU	Pilot Proj.
Germany	Nat. Leg.[a)]	Nat. Leg.[d)]	(Nat. Leg.)[c)]	EU	Vol. Agr.
Italy	EU	Vol. Agr.	(Nat. Leg)[c)]	EU	---
Netherlands	EU	Nat. Leg.[d)]	Nat. Leg.	EU	Nat. Leg.
Spain	EU	Vol. Agr.	Pilot Proj.	EU	---
Sweden	EU	Nat. Leg.	Nat. Leg.	EU	Vol. Agr.
UK	EU	Vol. Agr.	Pilot Proj.	EU	---

a) Countries which have been allowed to set national targets going beyond the EU Packaging Directive.
b) Flanders only
c) The brackets indicate that agreements are being negotiated or legislation is under discussion.
d) Voluntary commitment plus legislation
e) The national legislation was never brought into effect.
EU European Directive
Vol. Agr. Voluntary Agreement
Nat. Leg. National Legislation
Pil. Proj. Pilot Project

ECONOMIC FACTORS

(8) As a general guideline recycling of PVC will be established if it is profitable or – in case it is not profitable – if there exist legal or organisational measures encouraging or enforcing recycling. With the exception of the packaging sector which is being regulated by the Packaging Directive and some voluntary initiatives of industry which together constitute a considerable part of the existing post-consumer recycling activities the **major part of mechanical PVC recycling takes place under "free market conditions"**. It covers

– the whole area of the recycling of **pre-consumer wastes**

– and the recycling of **cables** in the area of post-consumer wastes.

"Free market conditions" means that the recycling is carried out for economic reasons, without legal obligations or subsidisation. The subsidisation of recycling can happen either by voluntary contributions (in case of voluntary recycling systems established by industry) or by non-voluntary fees (in case of legal obligations like in the packaging case). In other words, recycling under "free market conditions" is an economically profitable operation, where economic profitability can be defined in two equivalent ways:

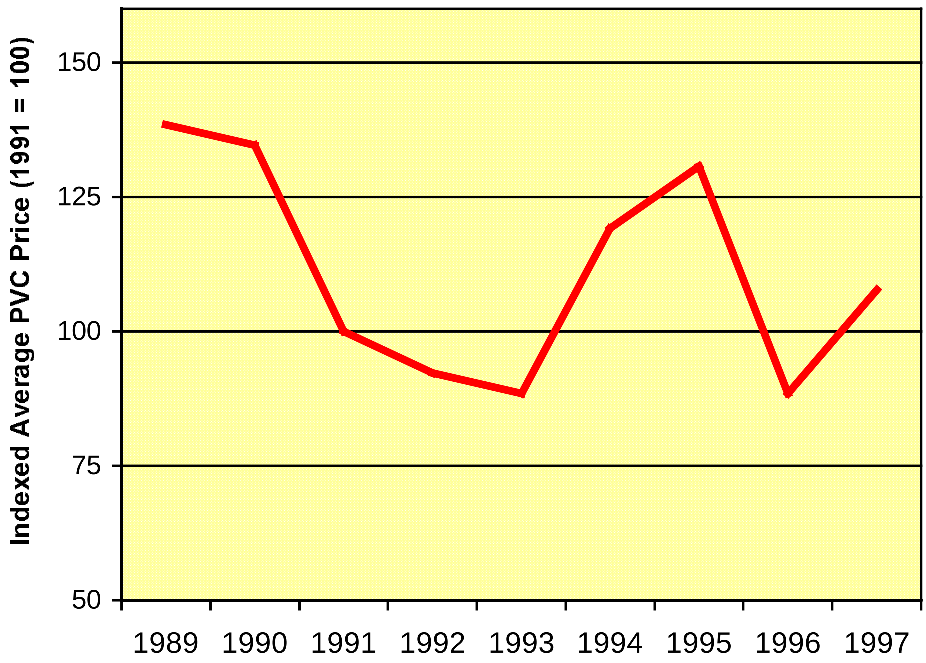
1. from the perspective of the marketing of the recyclates: The achievable price for recyclates is higher than the (gross) cost of PVC recycling (per ton of recyclate output) including collection, transport, sorting (if applied) and treatment minus the waste fees paid by the ”waste producers”;

2. from the perspective of the ”waste market”: The net cost of PVC recycling (cost for collection, transport, sorting and treatment minus credits for recyclates per ton of collected waste) is competitive to (lower than) the fees for alternative waste management options (landfilling and incineration especially).

For more detailed information on the costs of PVC recycling see Chapters 3.3 and 4.2 below.

Whilst the (gross) cost for PVC recycling including collection, transport, sorting (if applied) and treatment is more or less fixed depending on ”technical parameters” such as treatment technologies, geographical sites or collection systems, the economics of ”free market” PVC recycling can change greatly depending on the **price of virgin PVC** (which in turn influences the achievable prices for recyclates) and the **cost of ”non-recycling waste management options”** which compete with recycling on the waste management service markets. The price of virgin PVC has been subject to significant fluctuations in time and the cost of incineration and landfilling varies from country to country and region to region and may also fluctuate in time. Therefore, the economic profitability of ”free market” PVC recycling is not stable in time and may vary depending on the region.

Figure 2-3: Price Fluctuations of Virgin PVC



The economic profitability of the recycling of PVC pre-consumer wastes and PVC cable wastes is due to the following reasons:

– PVC **pre-consumer wastes** can be collected at low cost (using the distribution channels of the products, e.g. by combining delivery and take-back logistics) and in defined material qualities (separated by PVC compounds). Therefore, high-quality recyclates allowing for higher recyclate prices can be produced.

– The economics of the recycling of PVC from **cables** is determined by the fact that it is a **"secondary waste"**, i.e. a waste from the mechanical treatment of cable wastes. Cable recycling is carried out to recover the precious copper mainly. Therefore, for economic considerations the recycling of the PVC waste fraction starts at the gate of the cable recycler, not including the collection and treatment of the cables. Thus the recycling is profitable as soon as transportation costs plus/minus costs or credits for the processing (extrusion) of the material to new products are lower than incineration or landfill costs (including transportation). The costs of cable collection and treatment are not included in the PVC recycling costs but have to be covered by the proceeds from the marketing of the main product, i.e. copper and other metals.

For all the **other waste types** of post-consumer PVC, **mechanical recycling is not profitable** under present conditions. The existing recycling schemes for these wastes are either voluntary initiatives of industry or the result of the statutory requirements for the packaging sector, but have not been established for economic reasons.

The high recycling costs are mainly due to the high cost of separate collection and sorting (see Chapters 3 and 4 below).

ENVIRONMENTAL FACTORS

(9) Also when not being profitable in economic terms a promotion of recycling is justified when it provides environmental advantages. Mechanical recycling has been regarded as the ecologically most favourable waste management option. However, recent studies to assess the environmental performance of the mechanical recycling of plastics have shown that this does not apply principally but, depending on the recycling processes and the applications of the recyclates, the ecological advantages differ. Thus, the environmental advantages must be proven and significant in order to justify a promotion of recycling. There are two criteria which can be used to "measure" the environmental advantages of mechanical recycling:

- **Life cycle assessments**: The overall environmental impacts of the mechanical recycling must be smaller than the overall environmental effects of other waste management routes, landfilling and incineration especially. To account for the indirect savings of resources, energy and emissions which are achieved by the substitution of "virgin" materials by recyclates from mechanical recycling life cycle analysis is an appropriate method for this assessment.

- **Ecological and health risks**: If mechanical recycling is favourable in terms of life cycle assessments, the possible exposure of humans and the environment by single toxic or eco-toxic substances must be controlled in the recycling processes.

(10) **Life cycle assessments** on the recycling of PVC and plastics are available for a limited number of example cases of products and recycling routes only. Nevertheless, from the available results of selected recent studies (Table 2.4) it seems to be possible to come to the following general evaluation:

- For production wastes, cut-offs and post-consumer wastes from which PVC can be separated easily mechanical recycling provides an environmental advantage.

- Mechanical recycling of mixed plastics fractions provides environmental advantages only if it is feasible to sort out plastics materials which can be used in applications typical for plastics. The environmental performance of the recycling of mixed plastics for the production of products which substitute concrete, wood or other non-plastic applications is generally lower than the performance of other waste management routes such as energy recovery or feedstock recycling.

Table 2.4: Results of Life Cycle Studies on the Environmental Advantages of Mechanical Recycling of Plastics

Product/waste group	Results of related studies		
	Recycling system	**Ecological advantages of mechanical recycling**	**Reference**
1. Plastic production wastes	Recycling of collected production wastes compared to landfilling (incineration)	Savings: • Energy: 90% (66%) • CO_2: 97% (89%)	GUA 1998
2. Separately collected post-consumer wastes			
• PVC-windows	Window profiles with 70% recyclates compared to window profiles made of virgin PVC	Savings: • Energy: 40-53% • Air emissions (index): 56-69% • Water emissions (index): 47-64%	Weinlein 1996
• PVC-windows	Window frames with PVC profiles with 70% recyclates compared to the window frames with profiles made of virgin PVC	Savings: • Energy: 48% • GWP[a)]: 42% • Water emissions (index): 52%	EMPA 1996
• PVC-pipes	Sewage system with multi-layer pipes with 50% PVC recyclates compared to the sewage system with pipes from virgin PVC	Savings: • Energy: 10% • CO_2: 9% • NO_x: 16% • COD[b)]: 37%	EMPA 1998
3. Mixed post-consumer wastes			
• Packaging wastes	Recycling of separate collected plastics according to the present situation in Austria from household packaging wastes compared to landfilling (incineration)	Savings: • Energy: 37% (27%) • CO_2: 12% (16%)	GUA 1998
• Packaging wastes	Recycling of sorted plastics fractions from household packaging wastes compared to energy recovery	• Use of the recyclates in cable pipes: mechanical recycling advantageous • Use of the recyclates in waste bags: mechanical recycling not advantageous	Arbeitsgemeinschaft Kunststoffverwertung 1995
• Packaging wastes	Recycling of mixed plastics from household packaging wastes for use in products which substitute wood or concrete compared to energy recovery of the mixed plastics fraction	No advantage for mechanical recycling	IVV 1996

a) GWP = Contribution to the Greenhouse Warming Potential
b) COD = Chemical Oxygen Demand (Water)

(11) With regard to possible **ecological and health risks** associated with the mechanical recycling of PVC the general situation can be summarised as follows:

– Collection, sorting and treatment of plastics wastes is not associated with specific ”new” risks related with the exposure of workers and environment to hazardous substances. General risks like accidents in transportation processes or accidental fires in material stores do exist. However they are not specific for mechanical recycling but represent general risks existing in other waste management routes as well.

– Possible specific risks of mechanical PVC recycling are related with toxic substances in the recycling material. There are two major issues:

    - **Heavy metals and other additives**: Some PVC products like window frames, pipes and cables contain heavy metal stabilizers which (as single substances) are toxic (cadmium and lead compounds especially). A special matter of concern has been the cadmium stabilizers in window frames. In recent years the use of cadmium has been reduced significantly. However, it is still applied. Notwithstanding this development the old windows to be disposed of contain cadmium in significant amounts. When they are recycled mechanically, the cadmium stabilisers will be brought into new products. The evaluation of the associated risks has been a matter of controversial discussions: Since the heavy metal compounds are fixed in the PVC matrix a release of the toxic substances to the environment is not possible but in the production of the stabilizers, the compounding of PVC, waste disposal (incineration, landfill) and accidental fires. In general the quantities which can be released in this way are low compared to other sources of heavy metal emissions. Therefore the environmental and health risks of the stabilizers are regarded as not relevant by some experts. Others argue that for precautionary reasons toxic and persistent substances like heavy metals should be extracted from the technosphere principally and disposed of safely to avoid risks to health and the environment.[2]
    Generally the risks must be regarded as less critical in ”product-to-product” recycling systems (i.e. recyclates from window profiles are exclusively used in new window profiles) than in ”open” systems where the recycling material is used in a variety of other products, thus having no control over the substance flow. However also in the latter case the respective potential releases of heavy metals could be considered as low compared to other sources of heavy metals emissions.

    - **PCB in the PVC fraction from cable recycling**: In the past, polychlorinated biphenyls (PCB) were added to PVC cable compounds for some high voltage cables to increase the insulation performance and for low voltage cables as flame retardant and plasticizers (UBA 1999). A fraction of the cables contained

2) In the frame of this study it is not possible to discuss the heavy metal issue in depth, including all toxicological and ecotoxicological arguments and counter-arguments. Therefore we restrict ourselves on the description of the controversial positions and their respective consequences for the assessment of the potentials of mechanical recycling (Chapters 4.2 and 5.2).

in electric/electronic devices will be recycled in recycling systems for electronics wastes. Other sources of PCB and other toxic substances in electric and electronic wastes are transformer oils or condensators. As a consequence PVC recyclates from cable recycling and electric/electronic wastes recycling can be contaminated with PCB, which is brought into the products produced with the related recyclates. In contrast to heavy metals which are fixed in the plastics matrix PCB can be released from the plastics, thus constituting a chronic risk potential for health. PCB in products is subject to statutory regulations (see above). Recyclers and users of the recyclates are controlling the PCB content of the materials and are able to comply with the legal concentration limits. However, in Germany especially there are discussions and proposals to reduce the existing concentration limits down to a level where compliance of the PVC recyclates maybe not feasible (UBA 1999, see above). This would effect PVC recycling immediately. However, since PCB is not used any more, the restriction would be effective temporarily only, until the PCB-free materials will become wastes.

– There are some other issues related with PVC waste disposal and recycling which will not be discussed in this study since they are not connected with mechanical recycling (e.g. potential dioxin formation in thermal waste incineration or recovery).

(12) As a conclusion of this issue, the environmental impacts of mechanical recycling can be given for the different PVC applications (Table 2.5), taking into account the product-specific composition of the PVC compounds and the product-specific general potentials for a separate recovery,

Table 2.5: General Assessment of the Environmental Benefits of Mechanical PVC Recycling by PVC Applications

PVC Applications[b]	Environmental benefits of mechanical PVC recycling[a]	
	Life cycle improvements	**Control of toxic dispersion**
1. Construction Materials		
• Pipes (R)	+	–
• Window profiles (R)	+	–
• Other profiles (R)	+	–
• Floorings (S)	(+)[c]	–
• Roofing membranes (S)	– ?	–
• Cables (S)	– ?	–
2. Consumer and other short-life products		
• Bottles (R)	+	+
• Packagings (R)	–	+
• Other applications (separate PVC recovery)	+	+
• Other applications (no separate PVC recovery)	– ?	+
3. Cars		
• Components (R+S)	+	+
• Others (cable, coating)	–	–
4. Electric/electronics	–	–
5. Other Products (health, agriculture)	– ?	+

a) + = benefits through mechanical recycling; – = no benefits through mechanical recycling; ? = information lacking, no benefits expected through mechanical recycling

b) S = Soft PVC applications; R = Rigid PVC applications

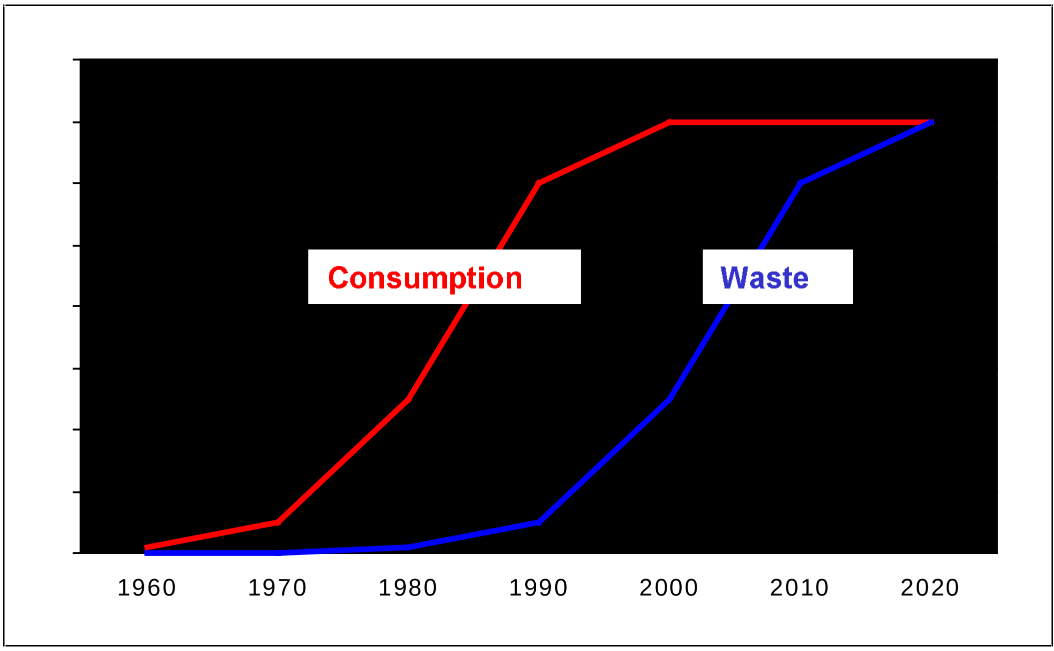
c) Contaminations (like sand) can cause problems for the recycling

3. PVC Wastes and PVC Recycling – the Present Situation

3.1 PVC Waste Arising and Recycled Quantities

(1) As mentioned above, there is a considerable time lag between PVC consumption and PVC waste arising which is due to the fact that a major part of PVC consumption is processed into long-duration products with lifetimes up to 50 years and more. Nevertheless there is a close linkage between PVC consumption and PVC waste arisings: With some exceptions "all PVC produced will become wastes sometimes, the only question is when", i.e. waste arising follows PVC consumption with a time-lag (see Figure 3-1).

Figure 3-1: Time lag between PVC consumption by processors and waste arising (schematically)



Data on the PVC production and consumption as well as data on PVC recycling are more or less available. They have been obtained from ECVM or EuPC respectively and from the surveys of published information and interviews of the related industrial associations and companies in the different EU Member States.

Data on PVC waste arisings in the EU are very uncertain. This is due to the fact that PVC ends up in a variety of waste streams whose total quantity may be known but not their PVC contents. Most data available on PVC waste arisings are estimations carried out by industry. They are deduced from the past consumption of the different PVC applications in computer models by using estimated average lifetimes of the products. The uncertainties are due to the uncertain life-times of the different PVC products and to our present "position on the waste function" shown in Figure 3-1 at the beginning of the dynamic part; i.e. the increase of waste quantities is comparatively high so that small differences between estimated and actual lifetimes of the products results in significant variations of the waste volume. The data have been discussed with ECVM and EuPC with regard to the underlying assumptions and have been cross-checked with data from other available sources as far as possible (see 3.2).

PVC PRODUCTION AND CONSUMPTION IN THE EU

(2) Quite reliable data are available for the production of PVC and the processors' consumption of PVC (see Table 3.1). It is to be pointed out, that post-consumer PVC waste arising depends primarily on the domestic consumption of the different PVC products. Due to various imports and exports of finished and intermediate products in the product chain, the domestic consumption of PVC in products is much more uncertain than the PVC consumption of the processors. In the waste models of industry rough estimates are used to account for these imports and exports, by applying correction factors (i.e. the relation of net exports of PVC in intermediate and final products to processors' consumption).

Table 3.1: PVC Consumption of Processors in the EU by product group (forecast for 1999, source: EuPC)[a)]

	PVC Consumption (compound)	
Product groups	1'000 tons	%
Building Products	4'250	57%
Packaging	680	9%
Furniture	102	1%
Other household/ commercial	1'346	18%
Electric/electronics	545	7%
Automotive	433	7%
Others	72	1%
Total	**7'429**	**100%**

a) Cable insulation is included in the product groups according to their use (building products for domestic installations, electric/electronics and car cables)

The **total consumption of PVC compounds** by PVC processors in the EU is about **7.4 million tons per year**. The PVC is converted to a variety of products. On a compound-basis about 50% of the PVC applications are flexible products and 50% are rigid products in the EU (on a polymer-basis: 1/3 flexible and 2/3 rigid products). With more than 50% of total PVC consumption the construction sector has the greatest importance for PVC. Pipes and fittings, window profiles, other profiles and cable insulations are the most important applications here.

In the EU the biggest consumer of PVC compounds is Germany where about ¼ of the total volume is consumed (Table 3.2). Italy, France and the U.K consume about 15% each (together 45%). Spain consumes less than 10% and all other countries less than 5%.

Table 3.2: PVC Consumption of Processors in the EU by Country (forecast for 1999, source: EuPC)

	PVC Consumption (compounds, rounded)		
	total (ktons)	% of Total EU	kg per capita
Germany	1.950	26%	24
Italy	1.260	17%	22
France	1.140	15%	19
United Kingdom	1.070	14%	18
Spain	580	8%	15
The Netherlands	330	5%	22
Belgium and Luxemburg	330	5%	32
Portugal	180	2%	18
Sweden	150	2%	17
Greece	120	2%	11
Austria	100	1%	13
Finland	80	1%	16
Ireland	80	1%	23
Denmark	60	1%	11
EU	**7'430**	**100%**	**21**

PVC WASTE ARISINGS IN THE EU

(3) As mentioned above, the present total arising of PVC in wastes is not known exactly. It has been estimated by EuPC on the basis of the time series of the PVC consumption by products and the life-time of the products. The results of these calculations have been analysed and adjusted to take account of the specific objectives of this study. The results can be summarised as follows:

- In 1999, available **post-consumer PVC wastes** amount to about 3,6 million tons per year (compound-basis).
- The volume of **pre-consumer PVC wastes** (production wastes and cut-offs) is approx. 500 ktons on a compound-basis.
- The **total volume of available PVC waste arisings** is therefore about 4,1 million tons per year.

The so-called **available waste** volume is the total quantity of PVC waste which actually ends up in the different waste streams, i.e. landfilling, incineration and recycling.[3] For some product/waste groups only a part of the total quantity of end-of-life products ends up as waste. Especially most pipes and cables in underground applications are not removed from the ground if they are worn-out.[4] They are available only if the old pipes or cables are replaced by new ones at the same sites, or if the ground is opened for other reasons occasionally. It has been estimated that this applies for 30% of the underground installations of these products only, i.e. the availability of end-of-life cables and pipes is 30%. For all other products the availability has been fixed at 100%.

(4) As mentioned above, the total quantity of PVC wastes develops dynamically at present, as a result of the introduction of long-life PVC products into the market in the 1960s and 1970s and the subsequent dynamic growth. The PVC consumption reached a saturation point not before the 1980s. Therefore, with product lifetimes of 30 years and more the saturation point of PVC waste volumes is still far from being reached. Consequently the total volume of post-consumer wastes is still less than 50% of the PVC consumption volumes.

The **range of uncertainty of the recorded PVC waste arisings** (based upon the EuPC data) which is in part the result of this dynamic development can be estimated at ±15%[5] on an average.

(5) Also due to the still low level of post-consumer wastes the share of **pre-consumer wastes** which are the easiest to recycle is still comparatively high (about 12%). However, sooner or later it will decline with increasing post-consumer waste quantities where reycling is more difficult than for pre-consumer wastes.

(6) As a result of the time-lag between PVC consumption and waste arising the **composition of PVC post-consumer waste arisings** by product groups is reversed to the PVC consumption structure (Figure 3-2):

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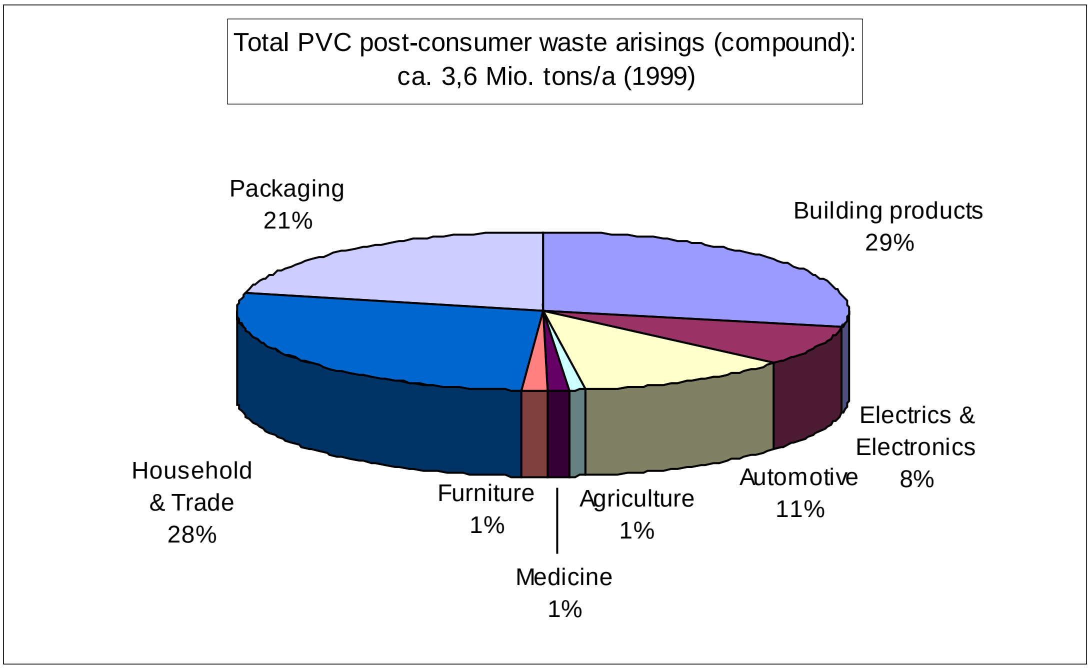
3) This definition is different from the definition used by EuPC and ECVM which refers to the waste quantity which is available for mechanical recycling, i.e. the maximum PVC quantity which theoretically (and in the future probably practically) can be separated by different recycling schemes from the different waste flows. The figure by ECVM for e.g. for the available post-consumer PVC waste in 1999 amounts to 2,7 m tons and is thereby ¼ lower than the 3,6 m tons used for this study.

4) This is not specific for PVC products but applies also for pipes and cables from other materials (e.g. concrete or cast iron pipes; polyethylene cables).

5) This estimation is based upon the expectation that the assumed lifetimes of the products may vary at most by 10 years on an average. Therefore the upper limit of the uncertainty range can be estimated with the difference between the calculated waste quantities for 1997 and for 2005. Also the comparison of the EuPC estimate with other estimates in the different Member States support the given uncertainty range: For example, EuPC estimates the present quantity for Austria at 40 ktons, which is close to the 43 ktons which have been estimated in an Austrian study (GUA 1998). EuPC estimates the PVC post-consumer waste arising for Germany at approx. 600 ktons which is about 13% higher than the 530 ktons estimated by the German association AgPU (AgPU 1999). The AgPU-estimate had been carried out on the basis of the estimated PVC content in major waste streams.
It must be stressed that the **EuPC estimate must be regarded as the best available estimation at present**, due to its very detailed data base on PVC consumption.

- Due to the fact that the major part of the long-life PVC products are made from rigid PVC the contribution of flexible products to post-consumer PVC wastes is about 2/3 on a compound-basis (50% on a polymer-basis), whilst flexible PVC amount to less than 50% (compound-basis) to total PVC consumption only.
- A major part of the flexible PVC applications are composite products or materials which are difficult to recycle or even cannot be recycled mechanically (e.g. coatings, organosols used for fabric products). For this reason the average recycling potential of the PVC waste volume is still lower than it might be in the future when the share of rigid PVC wastes will increase.

Figure 3-2: Estimated PVC Waste Arisings in the EU by Product Group 1999 (Basis: EuPC)

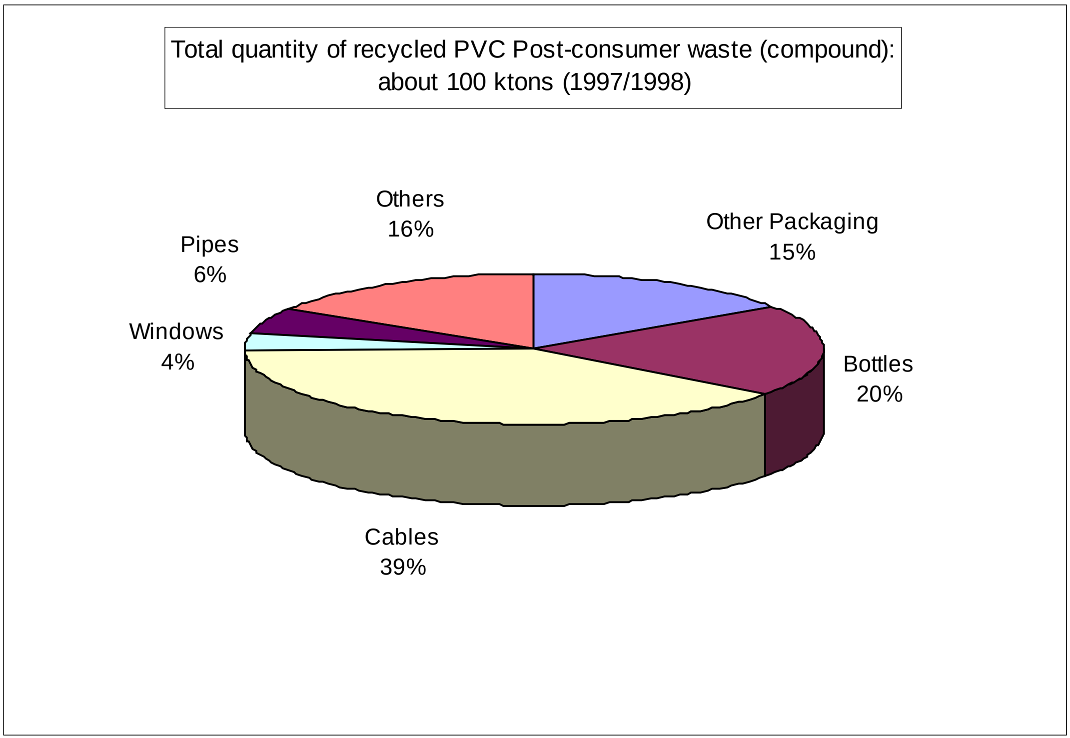


RECYCLED PVC QUANTITIES IN THE EU

(6) According to the result of an ECVM survey and the information received from the Member States about **520 ktons** of pre-consumer and post-consumer PVC wastes are recycled today:

- About 80% (**420 ktons**) of the recycled PVC wastes are **pre-consumer wastes**. This represents about **85% of pre-consumer PVC waste arising**.
- Recycling of **post-consumer PVC wastes** is still at a very low level in the EU. Today about **100 ktons** of PVC wastes (cf. Table 3.3) are mechanically recycled (Figure 3-3). This represents about **3% of post-consumer PVC waste arisings**.[6]
- The major part of post-consumer PVC recycling is in the areas cable wastes and packaging wastes. Cable recycling and a considerable part of packaging recycling is mixed plastic recycling, i.e. recyclates with a low quality are produced (see 3.2.2).
- High-quality mechanically recycling for post-consumer PVC wastes (i.e. production of pure PVC recyclates) exists for single product groups (bottles, pipes, window frames) only, with very low quantities yet.

Figure 3-3: Recycled PVC Post-consumer Wastes in the EU 1997/1998 (source: ECVM, Member States)



6) This figure does not include feedstock recycling which is applied for packaging wastes in Germany especially.

3.2 Overview of the Situation in the Member States

3.2.1 Overview of all Member States

(1) The following **systems** for the mechanical recycling of PVC **exist** in the EU at present:

1. To date PVC recycling is mainly recycling of pre-consumer wastes (see 4.1). ”Systems” for the mechanical recycling of **pre-consumer wastes** exist (more or less) in every Member State. This recycling is done for economic reasons and thus works under ”free market” conditions.

2. The major recycling systems for **post-consumer** PVC wastes in the EU are (Tab. 3.3):
   - recycling of **cable insulations** (in about half of the Member States);
   - recycling of **packaging wastes** in Austria, Belgium, Germany and Italy (mixed fraction) as well as in France, UK and Spain (separate bottle fraction);
   - recycling of **pipes** (in the Netherlands, Germany and Spain mainly);
   - recycling of **flooring** (in Germany mainly);
   - recycling of **windows** (in Germany mainly, covering also Austria and the Netherlands).

Table 3.3: Major Recycling Systems for Post-Consumer PVC Wastes in the EU (Source: ECVM, Member States)

Country	Mechanically recycled PVC waste quantities 1997/1998 (1'000 tons)								
	Bottles	Other packaging	Cables	Flooring	Roofing	Pipes	Windows	Others	**Total**
Austria		0,2	0,3	< 0,1	< 0,1	< 0,1	< 0,1	< 0,1	0,8
Belgium		1	0,1	0,2		0,5		0,1	1,9
Denmark			0,9		0,3	0,2		< 0,1	1,4
France	12		1					2,5	15,5
Finland								0,1	0,1
Germany		15	20	1,5	1,5	0,4	3,3	3,5	45,2
UK	1		5				0,1	0,7	6,8
Greece	< 0,1								0,1
Italy	1,6	2,9	3			0,2		0,4	8,1
Ireland									
Netherl.			3			2,7	< 0,1	0,3	6,1
Portugal	< 0,1								0,1
Spain			4,6			1,3		4,3	10,2
Sweden						< 0,1			0,1
Total	14,8	19,1	37,9	1,8	1,5	5,5	3,6	12,2	96,4

3.2.2 Austria

The PVC waste arising in Austria is estimated at 43’000 tons per year, where about 9’000 tons are pre-consumer wastes and 34’000 tons are post-consumer wastes.

About 6’500 tons of pre-consumer wastes are recycled (of which 3’500 tons are profiles). Thus, the recycling rate for pre-consumer wastes is approximately 70%.

About 750 tons post-consumer wastes are recycled, where cables are most important (300 tons). The resulting recycling rate for post-consumer wastes is approximately 2%.

The existing collection and recovery schemes in Austria are specific to products and wastes respectively, not to PVC. Collection systems exist for the following products:

- The collection of post-consumer plastic **pipes** is organised and financed since 1991 by the "Österreichischer Arbeitskreis Kunststoffrohr Recycling" (ÖAKR). The pipes are collected together with other plastic wastes and are sorted afterwards into four fractions: PE, PVC, PP and ABS. This system is operated by ABCO Abfallconsulting GesmbH, which performs collection and sorting and commissions recycling companies for the recycling of the material.

- The collection of used PVC-**windows** is organised since 1991 by the "Österreichischer Arbeitskreis Kunststoffenster" (ÖAKF). The collection, sorting and transport is done by 10 system partners. The windows are exported for recycling to Germany (VEKA). The windows are collected together with other plastic wastes and are sorted afterwards.

- The collection, sorting and transport of PVC **floorings** is performed by the "Oberösterreichisches Landes-Abfallverwertungsunternehmen" (LAVU). The floorings are exported to the recycling plant of the "Arbeitsgemeinschaft PVC-Bodenbelag Recycling" (AgPR) in Germany.

- Collection, transport and recycling of PVC **roofings** is part of the related German recycling system "Arbeitsgemeinschaft für PVC-Dachbahnen Recycling" (AfDR).

- As a consequence of the Austrian packaging ordinance, a system for collection, sorting, transport and recycling of **packaging** wastes has been created. The collection and sorting of plastic packaging is co-ordinated and organised by "Arbeitsgemeinschaft Verpackung" (ARGEV), the transport and the recycling by "Österreichischer Kunststoffkreislauf" (ÖKK). The system is financed by fees on the packagings. The PVC fraction in the packaging waste flow is very low. Therefore it is not separated in the sorting plants but remains in the mixed plastics fraction which is incinerated or used energetically. In addition to this a separate collection of PVC exists for pharma blister packagings in pharmacies, hospitals and ambulatories. About 220 tons per year (including aluminium) are recycled.

- In Austria banks and post-offices have established a voluntary take-back service for telephone and credit cards. This system is financed by the banks which take part in this system.

The collection and recycling of **cables** is carried out by waste management services and recyclers under “free market conditions”. The total arising of cable waste is unknown. Therefore the share of the separately collected cable waste is also unknown. Of the separately collected post-consumer cable waste nearly 100% is recycled, with the recovery of the metals (copper, aluminium) as the primary incentive. 60% of the mixed plastics-fraction from the cable shredders are further separated in specific plastic fractions (PE, PVC). Thereof 50% is recycled mechanically where the recovered PVC is reused for the production of industrial floorings mainly.

The joint capacity of all recycling plants amounts to 26’000 tons per year.

Both landfilling and incineration are less expensive than recycling. Thus, with the exception of cables there are no financial incentives to improve recycling.

In Austria there is no legislation to promote the PVC recycling. But there are several waste management ordinances relevant to PVC: Construction and demolition wastes have to be separated on-site in a manner that they can be recovered[7]. The Packaging Ordinance (1993) stipulates the separate collection of packaging wastes. According to the Ordinance on Landfilling the disposal of plastic wastes will be phased-out before 2004. Also relevant is an ordinance which bans the use of cadmium. However the reuse of recycling materials containing cadmium is exempted.

3.2.3 Belgium

For Belgium, no reliable data on PVC waste arising are available. The arising of pre-consumer wastes is estimated at 27‘600 tons (1997). Of this quantity about 80% or 21’500 tons were recycled. The major part of the recycled pre-consumer wastes originate from production and installation of pipes (8‘000 tons) and floorings (5‘000 tons). The rest is constituted by wastes from sheet/film (2‘000 tons), cables (1‘500 tons) and miscellaneous products including packaging (5‘000 tons).

The arising of post-consumer waste is unknown. About 1‘900 tons of PVC post-consumer waste were recycled in 1997. Post-consumer waste recycling includes packaging wastes, pipes, flooring, cables and sheet/films.

The recycling of packaging wastes is enforced by the national packaging regulation. The organisation Fost Plus has been founded to organise and finance these recycling activities.

7) However, there is no obligation to recycle the collected wastes.

For the other relevant wastes there is no specific regulation enforcing PVC recycling and there are no specific ”recycling systems”. Most of the recycling is carried out under ”free market conditions” by a variety of small and medium plastics recycling companies, few of them are recycling PVC together with other plastics. Hence, the major part of PVC recycling has to compete with landfill costs of about 60 – 80 Euro/ton and incineration costs of 80 – 100 Euro/ton.

The related PVC industry in Belgium intends to establish **voluntary recycling systems** for major PVC post-consumer wastes (e.g. pipes); however the preparations have not yet been completed.

3.2.4 Denmark

In Denmark the PVC pre-consumer and post-consumer waste arising amounts to approximately 34‘000 tons (1996). The PVC wastes originate from 3 primary sources, **construction and demolition** sector (C&D), **business** (offices and industries) and **households**, with approximately one third of the total quantity from each.

More detailed data are only available for C&D wastes: The waste arising is about 12‘000 tons. No distinction between pre- and post-consumer wastes could be done. About 90 tons (pipes) pre-consumer and about, 1‘410 tons (mainly cables) post-consumer wastes are recycled. The PVC recycling rate for post-consumer waste is considered to be high in Denmark: The PVC recycling rate for PVC C&D waste is at least between 10-15%. The recycling rate for production waste is nearly 100%.

A recycling plant for cables exists at NKT Cables and has a capacity of 10.000 tons cable scrap a year. The recovered PVC recyclates are used in the production of fillcasing in cables, hoses and signfooting. The quality of the recyclates is not equivalent to virgin material (see above). Recycled pipes are used together with virgin PVC as equivalent material.

The recycling of PVC is expected to increase in the coming years. New ways for treating PVC waste are being developed. NKT Research Centre is developing a process in which PVC is converted into materials, which can be used in the industry. The project is co-financed by the Danish Environmental Protection Agency, ECVM and Norsk Hydro. The treatment is not limited to mechanical recycling of PVC.

There is no financial support for PVC-recycling companies in Denmark with public funding. The organisation WUPPI, which collects rigid PVC from the construction and demolition industry, is financed by the shareholders, five producers of PVC-construction products.

In 1991 a voluntary agreement on the use of PVC was made between the Ministry of Environment and the Danish plastics industry and other trade organisations. The intention of the agreement is to ensure that the use of PVC safeguards optimally the interests of the environment and at the same time maintains the economic competitiveness of the Danish plastics industry. The goals of the agreement include: 1) to keep PVC away from ordinary waste incineration, where technically and economically justifiable; 2) PVC waste should be recycled, not landfilled; 3) the use of lead stabilisers and pigments and of chlorinated paraffins in PVC should be reduced to a technically and economically feasible extent; 4) for the evaluation of the environmental impact of PVC and other materials life cycle analysis can and should be used.

The voluntary PVC agreement has been replaced in June 1999 by the PVC strategy. The PVC strategy is not voluntary. The main objectives of the PVC strategy are:

- Banning the use of additives which are harmful to health and the environment in new PVC products;
- Keeping PVC wastes out of waste incineration plants, where possible;
- Finding substitutes, where possible, for PVC products which are difficult to separate from other wastes in the waste flow, to avoid PVC in waste incineration plants;
- Developing new treatment technologies to promote recycling of PVC waste;
- Collecting and recycling recyclable PVC;
- Discouraging recycling of PVC containing heavy metals.

In the governmental waste management plan 1998-2004 it is stated that PVC waste shall be separated from other kinds of waste in order to be recycled. If recycling is not possible then the PVC waste shall be landfilled. It is recommended that PVC is disposed of at separate cells at the landfill in order to allow easy access in case treatment later on becomes possible.

A tax must be paid for waste sent to incineration and landfill. Although this is not specific for PVC waste but is valid for all types of waste it improves the financial incentives for recycling.

In connection with the PVC strategy, a tax on goods containing (virgin) PVC and phthalates has been proposed recently. The tax is limited to product groups where the quantity of PVC and phthalate can be specified as a standard rate on the basis of product group's average content of PVC and phthalate and where it can be expected that the tax will result in a substitution of PVC and an increase of PVC recycling. The plastics industry and the PVC Informationsrådet (PVC information council) are against the tax. They argue that the proposed tax would have unbalanced effects on the Danish producers of rigid PVC construction materials especially, and the effects for the environment would be questionnable. The charge will for many ot the construction products match the contribution margin. The PVC policy should be formulated as joint EU initiatives.

3.2.5 Finland

The PVC waste arising in Finland is approximately 30.000 tons per year (no figures by product group available). There are no figures on the share of pre- and post-consumer wastes.

The quantity of recycled **pre-consumer** PVC wastes (production wastes) varies from 200 to 2'000 tons per year and depends heavily on the demand of the related PVC-products. In 1999 less than 1'000 tons will be recycled.

Less than 100 tons of **post-consumer** wastes (from the building sector) are recycled. There are no specific recycling schemes. Minor amounts of flexible PVC are used by cable manufacturers.

For Finland only a joint recycling rate for PVC pre- and post-consumer wastes can be given. With 1% to 6% it is very low compared to other EU countries.

There are two major reasons for the low recycling rate: First, PVC waste volumes are relatively small compared to other material flows in waste management. The average PVC content of municipal solid wastes is 0.2% only. The focus of recycling is oriented to other materials, which are more important from the national point of view and represent higher annual volumes. Secondly, a high proportion of more than 70% of all PVC is used for long-life products, such as pipes, in Finland. Consequently, the PVC post consumer waste arising is still small, unless the buildings or underground pipelines are demolished (time lag, see 3.1).

There are no specific regulations enforcing PVC recycling. The only general principle applicable for all types of wastes is the priority of mechanical recycling over material and energy recovery and final disposal, laid down in the Waste Act.

Voluntary agreements (between the packaging industries and the government) and limited recycling activities have been created for packaging materials covering also plastics. There is no emphasis on PVC, but the general provisions are applicable to PVC as well. Packaging manufacturers and importers finance the voluntary scheme by a fee on the price of packaging.

The Finnish Plastics Recycling Ltd. (Suomen Uusiomuovi Oy) was established in 1992. The main task of the company is to promote recycling by providing information on recycling possibilities for plastics. Markets for recycled plastics products are not very developed so far. The long transport distances are an additional economic constraint for recycling.

For the final disposal of PVC wastes only landfilling is practised in Finland. There are no municipal solid waste incinerators. Landfilling (with disposal costs of approximately 60 Euro/t) is much cheaper than recycling.

For the future, no major changes of legislation or voluntary agreements are anticipated in Finland. Small-scale pre-consumer waste recycling at production facilities will remain at current levels or marginally increase as a part of the production efficiency increase. The share of easy-to-recycle PVC waste is very small and consists of small material flows in production facilities. Most of the PVC waste is difficult to recycle and consists of different small fractions of post-consumer waste scattered in a large area with a small population density.

Due to the poor economic conditions for recycling companies regarding PVC and other plastics, it can be expected that a potential future improvement of plastics recycling will be restricted to the Helsinki Metropolitan Region, where about one million people (20% of the population) live in a radius of 40-50 km.

3.2.7 France

PVC **pre-consumer** waste arising amounts to about 40’000 tons in France. About 90% of this quantity (35’000 tons) are recycled. Production wastes are homogenous and easily available. As a consequence, they are recycled to a great extent.

PVC **post-consumer waste** arising amounts to about 450.000 tons per year. 15’500 tons of this quantity (with 12.000 tons mainly bottles) are recycled, resulting in a recycling rate of about 3%. The main reason for this comparatively low rate is the absence of recycling systems for the non-packaging sector.

Separate collection schemes for municipal solid wastes have been established in the last years, before the EU Packaging and Packaging Waste Directive came into force. Nevertheless, the efficiency has yet to be improved: only a part of the population participates effectively by sorting the waste. Eco-Emballages, the French organisation equivalent to the German "Grüner Punkt", is committed to improve the packaging collection rates through information campaigns.

Besides production wastes, the most important recycling stream has been mineral water bottles, which are collected separately, together with the other plastics bottles (especially PET). The reason for the success of the PVC bottle collection scheme is that bottles are provided at no cost to the recycling plant. Nevertheless, this activity is in decline due to the voluntary phase-out of PVC bottles (for economic and ecological reasons): in 1999 only 3‘000 tons will be recycled, after 12‘000 tons in 1998.

Recycling of automotive parts shall increase in the years to come. A voluntary agreement was signed in 1993 between the Government and car manufacturers aiming to reduce the waste for final disposal to 15% by 2002 and to 5% by 2015. Nevertheless, the recycled quantities remain at a modest level and amounted to 500 tons in 1997, with an increase up to 2‘000 tons expected for 1998.

There are also recycling activities beginning for electric and electronic equipment. So far the recyling rate remains at a low level. The government has set up some pilot projects (in Rhône-Alpes) in order to gain experiences and a take-back agreement is being discussed, so the development of a recycling scheme can be expected.

Despite the "green" construction sites projects promoted by Ademe (the French Environmental Agency), recycling of construction and demolition sites remains insignificant. Through the development of departemental C&D waste management plans, appropriate recycling schemes are likely to spread over the country.

Starting from the year 2000, wastes will have to be treated (mainly by incineration) prior to their landfilling. This may encourage the search for alternative ways to dispose of wastes.

3.2.8 Germany

The PVC waste arising in Germany is about 680 ktons per year. Thereof 150 ktons are pre-consumer wastes and 530 ktons post-consumer wastes. Germany is the Member State with the highest quantities of recycled PVC. Altogether about 180 ktons[8] of PVC are recycled mechanically. Three quarter of this quantity (135 ktons) is **pre-consumer** waste (120 ktons production wastes and 15 ktons installation cut-offs). The recycling rate for pre-consumer wastes is therefore about 90%. Mechanically recycled **post-consumer** wastes amount to 45 ktons. This is equivalent to about 8% of the PVC post-consumer waste arising. The major part of the recycled post-consumer wastes (20 ktons) is cable insulation waste. The other important part (15 ktons) is packaging waste that is recovered by the ”Duales System Deutschland”, the recycling organisation responsible to implement the German packaging ordinance. PVC packagings are not recycled separately but together with other plastics in a mixed plastics fraction which is used in products with low material standards (”downcycling”). With cable and packaging recycling together, three quarters of the mechanical recycling of post-consumer PVC can be classified as ”downcycling” (35 ktons).

Whilst the recycling of PVC in packaging wastes is enforced by the German packaging ordinance, pre-consumer recycling (100 ktons) and cable recycling (10 ktons) are carried out under ”free market conditions”, i.e. recycling is profitable economically. The other recycling systems existing for pipes, windows, flooring and roofing membranes are voluntary systems established by the PVC industry.

Pre-consumer recycling is carried out by a considerable number of small and medium plastics recyclers (not specialised on PVC) or the collected material can be returned directly to the processors without prior sorting or treatment. The recycling of **cable insulation wastes** from cable recycling is carried out by one company in Germany which uses the

8) In addition to the 180 ktons mechanical recycling about 10 ktons of PVC are recycled by feedstock recycling in Germany.

material for producing poles, industrial floorings and other products without pretentious material specifications. There are also considerable exports of cable insulation wastes for recovery in the United Kingdom. The **voluntary recycling systems** are managed by different organisations:

– There are two recycling organisations for **windows** with a combined recycling capacity of about 35’000 tons per year (two plants; cf. Chap. 3.3.2.3). Both systems recycle end-of-life windows together with pre-consumer wastes. The overwhelming part of the recycled quantities is constituted by pre-consumer wastes. The recyclates are used as a core material in new window profiles. The systems are financed by a fee on the collected windows.

– The **pipe** recycling system is financed by the plastics pipe producers and managed by their industrial association. The used pipes can be returned free of charge to a network of about 100 central collection points. The recycling systems includes pre-consumer wastes (cut-offs) and post-consumer wastes of all plastics pipe materials (besides PVC especially PE). Up to now the quantity of recycled post-consumer PVC pipes have been low (in 1998 approx. 160 tons out of a total input of 2’500 tons). Due to restrictions imposed by the related technical standards the use of the recyclates in new pipes is not permitted up to now. So the recyclates are used for the production of other products with low material standards (”downcycling”).

– There are two recycling plants with capacities of 5’000 and 6’000 tons per year for PVC **roofing membranes** and **floorings** (cf. Chap. 3.3.2.6). However the recycled quantities (post-consumer wastes) have been lower than 1’000 tons per year for each product. The collection is organised with about 20 central collection points in the case of floorings and pick-up at construction sites in the case of roofing membranes. Both systems are financed by a fee on the collected post-consumer wastes mainly. The recyclates are used in new floorings and roofing membranes in a separate backing layer.

As a conclusion, recycling of PVC post-consumer wastes has been at a very low level in Germany by now. This is partially due to still low levels of waste arisings (time lag between consumption and waste arising for long-life products), but the costs which are considerably higher than landfilling in most cases and (with the exception of pipes) have to be borne by the waste owner are likewise important. The economic competitiveness of recycling may improve in future if the national regulation on disposal sites which includes a ban of the landfilling of untreated plastics wastes by 2005 will be implemented. With increasing quantities the considerable logistic costs (the material has to be transported over large distances to one or two recycling plants) may be reduced as well.

3.2.9 Greece

For Greece the availability of data on the PVC waste arising is very limited. The sole figure which can be calculated is PVC in packaging, which end entirely in municipal solid wastes. This waste arising is estimated up to 1‘300 tons at present. Most PVC ends in long-duration products, some produced in Greece as pipes and profiles, but mostly imported.

The same lack of data applies for PVC recycling. Refering to the interviews carried out in Greece it can be assumed that most PVC converters use recycled PVC, with the exception of the bottle producers. The amount of recycled PVC can be estimated between 3-4% of the used virging PVC. This is equivalent to about 2‘000 tons PVC (Polymer). All this recyled PVC derives from **pre-consumer** wastes (production-/installation-waste, cuts-off). The sole recycled PVC from **post-consumer** waste are 60 tons **PVC-bottles**. Based upon these figures it is not possible to calculate or estimate a recycling rate for Greece.

The majority of the recycled PVC waste is imported **pre-consumer** waste. The recycling of pre-consumer waste occurs on the free market and is thus performed on a private basis. There are dealers who sell 20-50 tons lots of imported industrial scrap. There are also 2-3 tiny Greek companies which produce flakes from PVC waste recovered locally (very likely installation waste). The scrap is bought by compounders and converters.

The recycling of **post-consumer** waste is also performed on a private basis. **Packaging** collection out of municipal solid waste and the sorting of the packaging is currently financed by HE.R.R.A. (an association of industries consuming packagings) as voluntary programme. HE.R.R.A. has candidate itself to become the organisation responsible for applying the European Packaging Waste Directive in future. Their principle is to build 4-5 demonstrative sorting plants and to cover the deficit of their costs with the proceeds for sorted packaging. The remaining difference between the overall costs and the proceeds is paid by the municipalities and corresponds to the collection costs. There exist currently two systems for the collection of packaging:

- The municipality of Thessaloniki has established collection sites (containers) for different waste fractions. This type of collection generates practically only PET bottles.
- In the neighbourhood of Athens, in six districts, all packagings of all materials are jointly collected in kerbside four wheel containers. The people are instructed what has to be collected at home and to be brought to the containers. Also the rest of domestic refuse is brought to kerbside four wheel containers (of a different colour). All other planned future collection follows this model.

Out of the collected packaging waste, **PVC bottles** are sorted out by hand, together with some blisters and trays. There is currently only one recycling plant in Greece. The most important feature is the separation with gravity solutions. The capacity for PVC recycling cannot be determined since the plant is a multipurpose one.

Greece is in the process of replacing uncontrolled dumping with modern landfills. Landfilling cost is extremely low. The "pulling" factor towards recycling is the fact that Greece is a net importer of raw materials. But this obviously does not apply in periods as the present one in which prices are very depressed and, especially, products tend to be dumped in more peripheral markets as Greece.

3.2.10 Italy

The estimated arising of PVC **post-consumer** waste in Italy is in the order of 400-450 ktons per year. The amount of PVC in municipal solid waste can be estimated at 170 ktons per year. The recycled PVC quantity is estimated at 105 ktons pre-consumer wastes and 8,1 ktons post-consumer wastes (mainly packaging wastes and cables) in 1998. Therefore the recycling rate for post-consumer wastes is about 3%.

There are a number of "official" recycling systems concerning PVC post-consumer waste streams:

– CONAI (ex Replastic) - all packagings (PVC bottles)
– Progetto Italia - refrigerators and other appliances
– FARE - end of life vehicles

The first two are financed by fees. FARE belongs to Fiat and is financed by Fiat. The largest share of PVC recycling occurs however on the free market and is mainly pre-consumer-waste.

PVC is recycled by grinders, compounders and PVC processors. The normal PVC flow is from the waste collector to the grinder and further to the compounder and finally to the processor.

- The core of the **grinders'** business is milling. There are some companies with a large milling capacity (up to 100 ktons/year), of which only a share (10-30%) is devoted to PVC. The total number of PVC grinders is about 20.
- There are 60 PVC **compounders** in Italy and all of them recycle some pre-consumer waste. Whenever clean post-consumer PVC fractions are available, they are also recycled.
- There are about 6.000-7.000 PVC **processors** in Italy. Some of these companies are involved in PVC recycling in the sense that they buy PVC-waste to use them as raw material.

The total **recycling capacity** for PVC pre- and post-consumer wastes can be estimated up to 180 ktons/year (corresponding to a one shift operation):

- There are few recycling plants for **cables**. The joint recycling capacity of Tecnometal, Metalferro/Sarrme and ECVV is of about 12 ktons/y.

- The sole plant washing PVC **bottles** (with subsequent micronisation) has been closed. The capacity to select bottles is about 6 ktons.
- The washing capacity installed largely exceeds the quantities of PVC **agricultural film** wastes since it is dimensioned for PE films. One sole company (Rimaplast) has a treatment capacity which is over three times higher than the demand for PVC agricultural films.

Nearly all recycling occurs on the free market. Due to the low prices for virgin PVC, PVC recycling is decreasing at present. Especially the last two years have been particularly harsh for recyclers.

The principle that no organic material, other than the residues of recycling and composting, should end in landfills has been established by the **Ronchi Decree**. Theoretically this should apply from 1.1.2000 but all municipalities will ask for temporary derogations since none is expected to comply. There is a strong lobby in favour of incineration, which is still a small percentage of refuse disposal in Italy. This lobby is now finding allies among municipalities since it is much easier to incinerate than to recycle, giving an opportunity to meet the legal requirements more quickly.

All in all this Decree will not improve much mechanical recycling, at least on short term. More important will be actions demanding the recycling of durables (refrigerators, consumer electronics etc.). But these regulations will likewise be implemented in the frame of the respective EU activities.

The biggest recycling potential for the future exists in the area of construction wastes (pipes and profiles). However, by now there is no organisation in view which is capable of establishing a collection scheme.

3.2.11 Ireland

For Ireland there are no figures available, neither on PVC waste arising nor on PVC recycling. The new regional waste management plans set some targets for construction and demolition wastes and push for the separate collection at the construction site. How far this will have an influence on PVC collection is yet unknown. Experiences in other countries show, that e.g. concrete, bricks, wood, cables and plastics are collected. Plastics are often not separated by different products (e.g. pipes, profiles).

3.2.12 The Netherlands

The figures available for the Netherlands refer to pipes and cables, the two waste streams with a high recycling rate, as well as to floorings and window frames:

- Waste arising of PVC **pipes** and fittings amounts to 11‘200 tons per year, where 7‘200 tons are pre-consumer wastes (production wastes) and 4‘000 tons are post-consumer wastes (not including the used pipes that remain in the ground). 9‘900 tons are recycled, pre-consumer waste by almost 100% (7‘200 tons), post-consumer wastes by approximately 70% (2‘700 tons, taking into account the unknown quantity of worn-out pipes remaining in the ground, the recycling rate would be much lower).
  For post-consumer and installation wastes of pipes/fittings a dedicated collection system exists. It is a combination of pick-up service at the waste producers and a collection service with a network of permanent and temporary collection points. From the collection points the pipes are transported to the recycling plants. At the collection points the waste owners are paid as a compensation for their efforts to collect and store the PVC waste separate from other waste on the demolition site. These costs plus the costs for collection, separation, purification and regranulation are more than five times as high as incineration costs. They are borne by the related plastics pipe industry.

- The arising of PVC **cable** insulation waste is 16‘000 tons per year, where 1‘000 tons are pre-consumer wastes (production wastes) and 15‘000 tons are post-consumer wastes. More than 95% of the cable scrap is mechanically recycled, with recovery of the metal parts as primary incentive. The recycling rate of the plastics fraction is lower. 3‘800 tons of PVC cable insulation waste is recycled, pre-consumer waste by more than 80% (800 tons), post-consumer waste by 20% (3 ktons). This recycling rate is above the EU-average.
  The recycling of cables is performed under “free market” conditions, i.e. there is no dedicated overall recycling organisation for cable insulation wastes. Instead, there is a highly competitive market with about 20 shredding companies, linked to cable waste owners or waste management companies. In this "fighting market" the highly profit oriented companies go their own way.

- The waste arising of PVC **floorings** amounts to 8‘700 tons per year, of which 2‘800 tons are pre-consumer wastes (production wastes) and 5‘900 tons are post-consumer waste. 1‘800 tons of pre-consumer wastes are recycled at the production sites, representing a recycling rate of about 65%. The remaining 1‘000 tons are incinerated or partially landfilled.
  Recycling schemes for post-consumer wastes of PVC floorings have been conducted on a pilot basis thusfar. The company Forbo has participated in the German recycling organisation AGPR since 1990, giving Forbo the opportunity to send sorted PVC waste to the AGPR processing plant in Troisdorf. A regional pilot exercise in Arnhem was conducted in 1994 with flooring wastes collected at retailers or recycling stations and

sent to Germany for recycling. In 1995 the reprocessing of the wastes was switched to Forbo Coevorden in the Netherlands, where it was used for non-flooring applications. Recently (1999), a new process technology has been installed at Forbo, which allows for the use of the recyclates in flooring applications.

- PVC **window frames** are produced outside the Netherlands, mainly in Belgium and Germany. There is no domestic production. The frames are assembled in the Netherlands. Any production waste is directly recycled to almost 100%.
  For post-consumer windows a recycling system has been established by industry. The recycling organisation SRVKG covers the whole country and takes care of transportation, dismantling and return of the PVC frames to the producers outside the Netherlands. It manages the overall financing system, monitors the volumes, promotes recycling to the building industry and maintains contacts with Government, EU and third parties. About 40 tons per year of PVC have been collected in this system. There are no figures for the waste arising of post-consumer PVC window frames.
  The system is financed by a fee on imported PVC window frames and a disposal fee paid by the waste owners. The fee on imported window frames is 2.25 Euro per standard 3,6 m^2 window, i.e. 170 Euro per ton of window frame.[9] The participation of all PVC window frame importers is mandatory by a Ministerial Decree, issued on request of industry. The recycling fee for the waste owner is 45 Euro per ton. This is much lower than the cost of alternative means of waste disposal. Therefore, it is assumed that a high portion of all out-of-use frames are actually being offered for recycling.

For the mechanical recycling of PVC wastes there are two recycling plants with a total capacity of about 10’000 tons per year.

The major part of PVC wastes which are not recovered or recycled are sent to incineration. The landfilling of combustible wastes (including plastics in general) is prohibited since 1997. A legal transition period is now in place. The **policy** of the Dutch government concerning PVC is to stimulate more recycling schemes for PVC products. The PVC industry supports recycling wherever economically justified, technically feasible and leading to environmental gains without compromising product quality. Besides pipes and cables also floorings and window frames meet this condition. There is also an **“Action Plan Building an Demolition Wastes 2000”** existing, a joint implementation by authorities, industry and waste management companies to improve recycling of construction and demolition wastes. Furthermore, there exist **voluntary agreements** between the Dutch Government and the PVC industry on the recycling of pipes/fittings and window profiles. For cables no PVC specific measures are in place apart from the existing industrial practice. The PVC industry promotes their recycling programs by **promotion campaigns**.

9) Crudely assuming that recycling of the 25% metals part can be financed from the metals revenue, this corresponds to 58 Euro per ton of PVC polymer.

In the future at least the absolute amount of PVC recycling will increase due to the long-life products installed in the 1960s in the building sector coming to the end of their service life. Especially for pipes a future problem will be that waste owners prefer to leave the pipes in the ground, avoiding the excavation costs.

3.2.13 Portugal

Portugal has a consolidated PVC recycling industry, large in proportion to the dimension of the country, but small in an European context. There are no figures on the PVC waste arising available.

Only **pre-consumer** wastes (industrial wastes) used to be recycled by now, in 1997 some 1’100 tons. Since 1998 there exists a system for **post-consumer packaging** recovery and recycling. France has been taken as model. The system is managed by the parent company "Sociedad do Punto Verde" (Green Dot System) which controls different subsidiary companies responsible for the recycling of the different packaging materials. The one for plastics is called "Plastval". Portugal still consumes a large quantity of PVC **bottles**. In 1998, when the system started, 24 tons of PVC bottles were collected by the system. By spreading the system all over the country, it is expected to rise the collection up to 120 tons this year.

In Portugal there are also recycling activities for post-consumer **cables** to recover copper. It is unknown what happens with the cable insulation.

All in all the main recycling activities remain limited to industrial PVC wastes including industrial packaging which will be included in the Green Dot System very soon.

3.2.14 Spain

Estimations of PVC waste arisings by ECVM and EuPC range from 150 ktons up to 250 ktons per year for Spain. In proportion to Italy (per capita waste arising) it seems more reasonable to estimate the PVC waste arising with 200-250 ktons per year (the PVC consumption is about 500 ktons per year). A distinction between pre- and post-consumer wastes was not possible due to lacking data.

The total amount of recycled PVC waste can be estimated with **45 ktons** per year, of which 35 ktons are pre-consumer wastes (about 40% of this amount is imported industrial scrap, the rest are cables, flexible films and sheets from domestic sources mainly) and about 10 ktons post-consumer wastes (cables, garden hoses, pipes and profiles). The estimated recycling rate for post-consumer wastes is in the order of 4%.

Cables are recycled in the two largest recycling companies both in Catalonia: "Recuperaciones Emsa" which produces floor tiles and "Tecniplasper" which produces compounds, mostly for the production of garden hoses.

Pipes, **profiles** and **garden hoses** are collected by some municipalities which have agreements with construction companies to improve recycling by keeping demolition wastes separated by material fractions on the construction sites.

The collection and recycling of **packagings** has been organised taking France as a model. The operative company is called Ecoembalajes España (EE) which is also responsible for the financial organisation. Packagings are collected and sorted by the waste management services of the municipalities, but EE pays for the cost. This system is organised on the basis of contracts with a duration of one year. In Spain, PVC has almost disappeared from packaging. Only some blisters and films are recovered. Still in 1996 the PVC fraction was about 500 tons due to bottles. Meanwhile some 30 mineral water producers (including the principal companies) have voluntarily decided to phase out PVC bottles and to use PET bottles instead.

There exist two non-profit companies: "Revinil" since 1993 and "Cicloplast" since 1996. Both have been established to promote recycling (Revinil only PVC, Cicloplast all plastics).

There is also a well-established recycling industry for PVC pre-consumer wastes in Spain which processes also post-consumer wastes now. This industry operates in a “free market system”.

As a result of the increasing concern about environmental risks in connection with PVC, the government has created a **commission** - consisting of representants from manufacturers and ecological organisations - in order to evaluate the environmental impact of PVC. For the time being, no further measure has been taken.

A major problem for the future is the collection of post-consumer wastes. The largest potential waste is probably pipes but up to now no organisation has been established to manage their systematic recycling. So, if no furrther legal initiatives will be taken the **future prospects** for PVC post-consumer recycling will depend on the development of the economic conditions (virgin PVC prices and disposal costs). This means that the situation in Spain is similar to the Italian one.

3.2.15 Sweden

The total quantity of **production wastes** (pipes and floorings) in Sweden is approximately 14‘400 tons per year. For the installation wastes no figures are available, i.e. the total quantity of pre-consumer wastes is not certain. Most of the PVC production waste is mechanically recycled plus 200 tons per year of installation waste.

Total PVC **post-consumer** waste arising is about 40‘000 tons per year. Less than 100 tons (pipes) are recycled, resulting in a recycling rate for post-consumer wastes of less than 1%. Hence, the recycling of post-consumer waste is negligible compared to pre-consumer waste.

In Sweden recycling organisations for **pipes and floorings** have been established. The system for pipes covers all steps except transportation, which is covered by the wholesaler. The system for floorings covers collection and transportation. The sorting and recyling is in the responsibility of the producers. The recyling is financed by the manufactures of pipes and floorings through fees. The recycled material produced is qualified for „high-quality“ uses.

There exist **recycling plants** for PVC pipes and floorings which also recycle wastes from outside Sweden. The current capacities of these plants are 1‘500 tons/year and 15-20‘000 tons/year respectively.[10]

So far there is no **legislation** with respect to the recycling of PVC wastes. The Waste Action Plan (Naturvårdsverket 1996) and the Government Proposal (97/98:145) include general recommendations which apply also for wastes containing PVC. The Government Proposal (97/98:145) includes restrictions on PVC additives: The use of DEHP and other plasticizers in PVC products that may be hazardous to health or environment should be phased out by 2001 for outdoor applications and by 2005 for other applications (voluntarily, no legal requirement). The use of tin and lead stabilizers in PVC products should be phased out as well (voluntarily, no legal requirement).[11]

There are also specific regulations requiring the recycling of cars, electric/electronics and packaging wastes. They include no specific regulation for PVC but the respective PVC fractions are also included in the recycling activities.

Furthermore, a **voluntary agreement** exists between the Government and the construction industries to reduce the amount of waste going to landfills and to increase recycling.

As for the **final disposal** of PVC, a general ban for landfilling of combustible wastes has been passed beginning in 2005. The combustible waste fraction must be separated from the non-combustible fraction. At present the disposal on landfills is still possible. It is cheaper than recyling. Thus, financial incentives for recycling are weak.

3.2.16 United Kingdom

Besides Germany, France and Italy, the United Kingdom is the Member State with the largest quantities of PVC wastes recycled. The total quantity of PVC **pre-consumer** waste is about

10) The capacities may be upgraded by multi-shift operation.
11) For tin stabilizers the National Chemicals Inspectorate has to propose a phase-out plan. The phase-out of lead stabilizers should be completed not later than 2002.

67 ktons per year. Thereof about 54 ktons or 80% are recycled (mainly in the production and installation of window profiles).

Total PVC **post-consumer** waste arising amounts to 145 ktons per year. About 7'000 tons or 5% are recycled, of which the major part is cable waste (5'000 tons).

There is no specifically created PVC recycling organisation in the UK. All recycling is carried out on a commercial basis by **recycling companies**. There are about 30 companies which, for at least a part of their operations, make a business from handling used PVC. They can be involved in any stage of the recycling process, including collection, sorting and reprocessing. Specifically for plastics **bottles** (of all polymer types), there is an organisation called Recoup which facilitates plastics bottle recycling (including PVC). It has a membership subscription which is used to support Local Authorities' collection of bottles, to provide them with expertise and advice to develop an end-use market for the recycled material.

Due to the increasing tonnage of PVC waste arising in the next 10-30 years (particularly building products), recycling is expected to increase also, especially in window and pipe applications where the quality of recyclate is good.

However, compared to landfilling and incineration the recycling of PVC is quite expensive. Thus the financial incentives for recycling will remain weak.

There are also no national measures specifically relating to PVC recycling. The only specific **legislation** of relevance so far is the UK Packaging (Producer Responsibility) Regulation 1998, which represents the UK's transposition of the EU Packaging and Packaging Waste Directive and covers all packaging materials. The PVC industry in the UK is represented by the British Plastics Federation (BPF), which has a communications programme featuring the recycling of PVC as one aspect of environmental performance. An important agreement affecting PVC recovery/recycling is a **"Charter"** currently being worked out between the UK PVC raw material producers and a group of retailers (being brokered by the National Centre for Business and Ecology). The Charter includes a commitment to develop an agreement on "eco-efficiency" which means minimising quantities of used PVC products to landfill. There are no legal limits to the landfilling of PVC or indeed any other plastic in the UK.

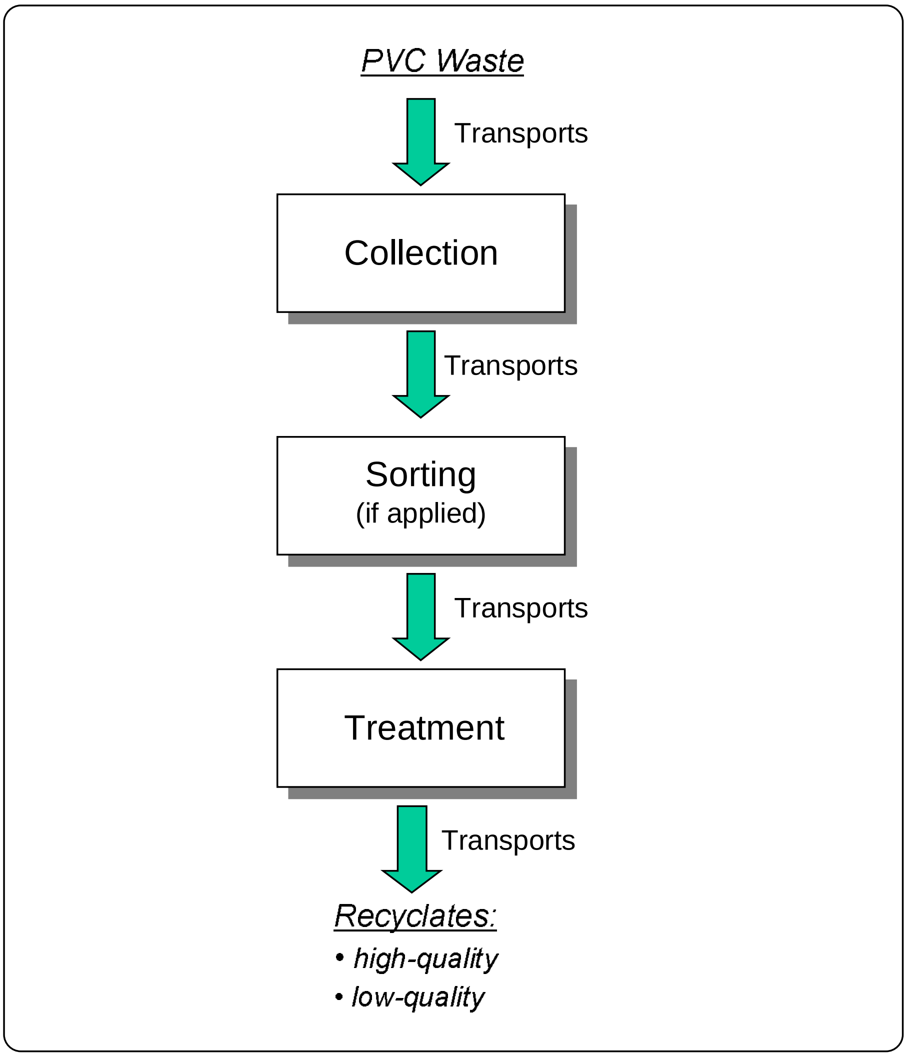
3.3 Description of Existing PVC Recycling Systems

3.3.1 Overview

(1) In order to describe the existing systems for the mechanical recycling of PVC published information has been evaluated and interviews have been carried out in the different Member States. For this purpose a standard questionnaire has been used (see Appendix A.3). The interviews have been carried out by telephone and personally.

(2) The term "recycling system" includes the whole material chain starting with the PVC waste at the place where it arises and ending with the recyclates which are used for the production of new products (Figure 3-4).

Figure 3-4: Recycling System for PVC Wastes (schematically)



The material flow can include the following steps:

- **collection** of the wastes, e.g. in pick-up systems or bring systems, in pure or mixed fractions;
- if the PVC wastes are collected in mixed fractions (e.g. mixed packaging wastes) some fractions may be separated in **sorting** plants to obtain pure materials for further treatment;
- **mechanical treatment** processes aiming at the (more or less) automatic separation of pure fractions of PVC and other materials and the production of recyclates with a defined particle size; generally the mechanical treatment process consists of shredding units for size reduction, separation units to extract specific sizes or materials from the main material flow (e.g. magnetic drums to separate ferrous metals) and mills and extruders to convert the separated plastics fractions into re-granulates.

Between each of these steps transports may be necessary depending on the organisation and the location of the related plants.

With regard to the **recyclates** produced we distinguish between (see Chapter 2.2.2)

- **"high-quality recyclates"** which due to their low degree of contamination can be re-used in the production of the same products and
- **"low-quality recyclates"** which can be used as a substitute for "non-PVC-materials" only, generally referred to as "downcycling" (e.g. general plastic, concrete or wood products).

The "recycling system" is not only characterized by the material flow and the related technical collection, sorting and treatment methods but also by its **organisation**. This includes the way the material flows are managed (e.g. specific recycling organisations or free market) and the type of financing (e.g. waste fees or fees on the price of the related products) especially.

(3) In order **to describe the different recycling systems** the following **criteria** have been used:

- Methods and technologies:
  - collection
  - sorting
  - treatment
- Capacities and quantities: capacities of the recycling plants and annual quantities of recycled PVC wastes
- Input: origin and composition of the recycled wastes (post-consumer/pre-consumer; mixed/pure)
- Output: quality (composition, degree of contamination) and use of the recyclates
- Geographical area covered, transport intensity

- Organisation: free market system or specific recycling organisation; duties and competences of the recycling organisation
- Financing: who pays the recycling costs?
- Costs: overall cost of the recycling chain (gross cost and net cost including credits for recyclates).

Some of the systems which have been analysed will be described subsequently.

3.3.2 Description of Selected Recycling Systems

3.3.2.1 Mechanical Recycling of Pre-Consumer PVC Wastes

(1) For the mechanical recycling of pre-consumer PVC wastes a variety of ”recycling systems” exist. Cut-offs and production wastes are either given back directly to the relevant PVC converters or they are treated mechanically to produce recyclates of a defined size and quality. The recycling is not organised by special recycling organisations but there exists a market for PVC pre-consumer wastes which depends on price considerations.

The free market recycling structure consists of different, mainly small and medium enterprises which are occupied with one or several of the major operations in the recycling cycle: collection, grinding, compounding and processing (i.e. users of the recycling materials). There is no specific structure for PVC wastes, but the whole spectrum of plastics recycling is covered. For example in Italy about 20 grinders and 60 compounders recycle PVC. The number of PVC processors is 600 – 700.

There is a close linkage between the recycling market and the market for virgin PVC: The recycling activities fluctuate with the price for virgin PVC to some extent. If virgin PVC prices are down the economic feasibility of some of the recycling activities ceases and they are stopped until the virgin PVC prices exceed a certain level again. In Italy, the production of PVC recyclates fell from about 120.000 tons to 110.000 tons between 1997 and 1998, as a result of the drop of PVC prices.

(2) It follows a description of the mechanical recycling of pre-consumer PVC wastes by using the above mentioned criteria as far as sensible.

– **Methods and technologies:**
  - The PVC wastes are **collected** by the PVC processors (production wastes) and the users of PVC intermediate products (e.g. the packaging industry using PVC films) and the handicraft enterprises installing PVC floorings, roofing membranes and other products.

- Depending on the specific application the PVC wastes must be treated in a **mechanical** process (grinding) to produce regranulates of a defined size and composition. Some of the plants for the mechanical treatment of pre-consumer wastes simultaneously process PVC post-consumer wastes.

- The recycling material can be bought by compounders which often blend it with virgin PVC to produce compounds of a defined quality.

– **Input:**
The economic feasibility to recycle a specific type of pre-consumer wastes depends on the degree of contamination (e.g. sand, dirt), the defined formulation of the material and the deliverable quantities. Most production wastes can be collected in a defined specification, in some cases (e.g. recycling of cut-offs of a packaging producer using the products of a specific PVC film producer) even in a defined formulation. The recycling of cut-off wastes from the laying of floorings, cables, pipes etc. is often more difficult, for most are mixtures of PVC compounds from different PVC processors and they may be contaminated or they are collected together with other plastics (e.g. plastic pipes) making additional washing and/or sorting necessary before grinding.

– **Output:**
In general the recycling of pre-consumer wastes yields high-quality recyclates: A part of the recyclates can be used by the PVC compounders or processors as an equivalent for virgin PVC. The other part can be used for example as separate layers in co-extruded PVC-products (e.g. profiles with a core of recyclates) or as backing material of floorings, i.e. it replaces virgin PVC, but not ”1:1” (for example due to unspecified colours).

– **Organisation:**
There is no specific recycling organisation but the recycling activities are driven by the ”free market” (see above).

– **Financing:**
As a result of the ”free market” system the recycling is ultimately ”financed” by the waste producers. Ideally, every actor in the material chain (recycler, collection service, transport service) charges cost prices for his services. The recycling is finally profitable if the net recycling costs (collection plus transport plus treatment minus proceeds for recyclates per ton of waste collected) can compete with waste disposal prices (esp. landfilling or incineration) – or from the other point-of-view – if the gross recycling costs per ton of recyclate output (at a given fee on the waste arising) are lower than the achievable prices for the recyclates.

– **Costs:**
The recycling costs for pre-consumer wastes vary depending on the specific case and type of wastes. Thus no general valid cost figure can be given but only an order-of-magnitude of the recycling costs. According to published information (GUA 1998,

Brandrup 1995) the following cost ranges can be given (per ton of recyclate output):

- collection, sorting and transport: 100 – 150 Euro per ton
- treatment (re-granulation): 270 - 500 Euro per ton,

where the lower limit of the treatment costs applies for pure plastics wastes without contaminations requiring grinding and extrusion operations only, and the upper limits for pure plastics wastes with contaminations requiring additional washing, drying and separation operations. Thus **total recycling costs** may vary between **370 and 650 Euro per ton**. For grinded material (without extrusion) the costs may be 100 ECU/t lower. Today, the achievable prices for grinded PVC recyclates range from about 200 to 450 Euro per ton depending on the quality (esp. specified white colour or not). Thus pre-consumer recycling is not profitable in all cases today. Mainly pure material fractions (PVC fractions without contaminations) which do not require extensive treatment to yield high-quality recyclates are required to reach profitability. However, the prices for virgin PVC are at a very low level at present. Due to the linkage between virgin prices and recyclate prices the recovery of virgin PVC prices will result in an increase of pre-consumer PVC recycling.

3.3.2.2 Mechanical Recycling of PVC Cable Insulations

(1) As for the mechanical recyling of pre-consumer PVC wastes, the recycling of cable insulations is not carried out by specific recycling organisations but there exists a **"free market"** for these wastes. PVC cable insulations are recycled for pure economic reasons, i.e. the recycling is a competitive or near-competitive waste management option. Therefore, like in the case of pre-consumer wastes, the recycling activities fluctuate with the price for virgin PVC and the prices for alternative waste disposal options for the PVC wastes.

Post-consumer PVC cable insulations arise as a waste fraction in the mechanical recycling of cables. It is a mixed plastics waste which contains also other plastics and contaminations. As mentioned in Chapter 3.2.2, being a secondary waste, it constitutes a special case amongst the post-consumer PVC wastes: The material is already available in its final form for extrusion into new products. The primary objective of cable recycling is the recovery of the copper content of the cables. Therefore, for the cable recycler the costs of cable collection and treatment are attributed to the primary outputs of cable recycling, i.e. copper and other metals (e.g. aluminium). The PVC waste fraction is a cost factor only. Thus its recycling is profitable as soon as transportation costs plus/minus costs or credits for the processing (extrusion) of the material to new products are lower than the cost for incineration, landfilling or possibly energy recovery (including transportation).

(2) It follows a general description of the existing cable recycling activities in the EU (Austria, Belgium, Denmark, France, Germany, the Netherlands, UK, Italy and Spain).

– **Methods and technologies:**

- **Collection:** The cable insulation material arises as an output of cable recycling. Hence there is no collection as such, but only the transportation from the cable recycler to the user of the recyclates (plastics processors).

- **Treatment:** Generally the material is used by plastics processors, e.g. for the extrusion or injection moulding of plastics products, without extensive prior mechanical operations.

– **Material quality and use :**
The PVC cable insulation material is a **mixed plastics fraction** containing about 80% PVC compounds (approx. 50% of pure PVC and 50% plasticizers, fillers and other additives, e.g. lead stabilizers). The remaining 20% are other plastics such as polyethylene including about 2% percent of contaminations (e.g. residual metal content). The material is used for applications similar to the products of mixed plastics recycling, e.g. poles for roads, industrial floorings and other products substituting concrete and wood products. The presence of metals residues in the plastics fraction prohibits the recycling as cable insulations.
The plastics material can contain **PCB** due to the recycling of older cables where PCB has been used as an additive to PVC compounds (see 2.2.2). Therefore regular measurements are being carried out. According to the interviewed recyclers the limit value of 50 mg PCB per kg can be achieved generally. However there are discussions to reduce the standard down to 5 mg/kg, in Germany especially (UBA 1999). According to the recyclers, compliance with this value will hardly be possible. Another environmental issue is the content of toxic lead additives. It is discussed in more detail in Chapters 2.2.2 and 4.2.1.
There is a considerable **trade** with cable scrap, both inside the EU and with countries overseas. A considerable quantity is delivered to processors in the UK. In the interviews with recyclers, exports to Asia were also mentioned. The control of these waste flows is being assessed in the framework of the Basel convention which is discussing the potential classification of this waste as hazardous waste and is also drafting a guideline on plastics waste management.

– **Organisation:**
There is no specific recycling organisation but the recycling activities are driven by the ”free market” (see above). The actors in the market are cable recyclers, trading companies and plastics processors.

– **Financing:**
As a result of the ”free market” system the recycling is ultimately ”financed” by the waste producers, i.e. the cable recyclers on the basis of economic considerations (recycling fee versus fee for other waste management options).

– **Costs:**
Exact cost calculations have not been made available by the recyclers. Based upon

information of interviews with recyclers, we estimate the order-of-magnitude of the costs as follows:

- The **total net cost** ex cable recycler is **lower than 50 Euro/t** which is the present fee to be paid by cable recyclers to traders or processors.
- The costs of the **plastics processors** using the recycling material differs depending on the products which can be produced and the processing technology. According to the information obtained, the net costs (processing costs for extrusion or injection moulding minus proceeds for the final products) are around 0. In some cases the processor gets a fee for taking over the material, in some cases he pays for it.
- **Trading** of the material even over longer distances is economically attractive in some cases. An example is the export from Germany to the UK, where the transportation costs are nearly covered by the reimbursements of the processors. In addition, the cable recycler in Germany pays a fee which is well below the prices for landfilling.

3.3.2.3 Mechanical Recycling of PVC Window Frames in Germany

In Germany two recycling systems for PVC windows have been established:

– the **”VEKA system”**, an investment of the window profile producer VEKA AG who has established a recycling plant for pre-consumer and post-consumer window profile wastes in Thuringia;

– the **”FREI system”**, an organisation founded by 14 profile producers which has established a system of collection points at local recycling companies and cooperates with a recycling plant in North Rhine-Westfalia.

The following description refers to the VEKA system mainly, whose recycling plant has been visited. Major differences to the FREI system are pointed out.

– **Methods and Technologies:**

- **Collection:** There exist two major pick-up systems: Collection by the transport services of **VEKA** at window producers/assemblers and collection by independent container services at construction sites or window producers.
  → In the first case the collection of old windows has been integrated into the take-back system for cut-off wastes (pre-consumer wastes). Based upon co-operation contracts, VEKA takes back the cut-offs together with the old windows if a minimum threshold quantity is reached. To date the old windows are no more than a marginal position in the system, since the major quantities are cut-off wastes. For each old window a charge of 25 DM is raised, i.e. approx. 500 DM or 255 Euro per ton (incl. pane). This system is used for old windows from renovation projects mainly.

→ In the second case, the old windows are picked-up by independent container services, which co-operate with VEKA but work on their own account. This system is used mainly for the pick-up at construction sites, e.g. in case of demolition projects or for small window workshops who do not produce sufficient quantities to fill a complete lorry. In this case the container services are charged between 70 and 250 DM/t (f.o.b. VEKA recycling plant), depending on the degree of contamination and whether the cart-load contains window panes or not. The owner of the old windows pays directly to the container services who has to cover the VEKA charge, the transportation costs and his margin.

The **FREI** recycling system is organised as a bring-system: A network of more or less centralized collection points has been established (about 110 collection points distributed over Germany), there the old windows can be delivered. The transport to the collection point is organised by the owner of the old window on his own account. The charge for the old windows f.o.b. collection points is 15 DM per window (approx. 300 DM or 150 Euro per ton). The charge for delivery at the recycling plant is 200 –300 DM per ton.

- **Sorting and mechanical treatment:** The **VEKA** recycling plant has been constructed on the principle of maximum automatisation. The mechanical treatment process consists of the following major unit operations (Figure 3-5):
  → shredder unit;
  → magnetic separation of Fe-metals;
  → screening unit where the coarser fractions are fed back to the shredder (directly or after passing a non-ferrous metal and rubber separator);
  → the fine fraction passes separation units for glass and residual metals;
  → wet grinding unit with subsequent rubber separation;
  → colour separation (in a coloured and a white fraction);
  → extrusion to regranulates with microfiltration to remove residual contaminations.

  One speciality of the process is the colour separation. However, this unit is still in the process of technical optimisation. At present an improved system is being installed.

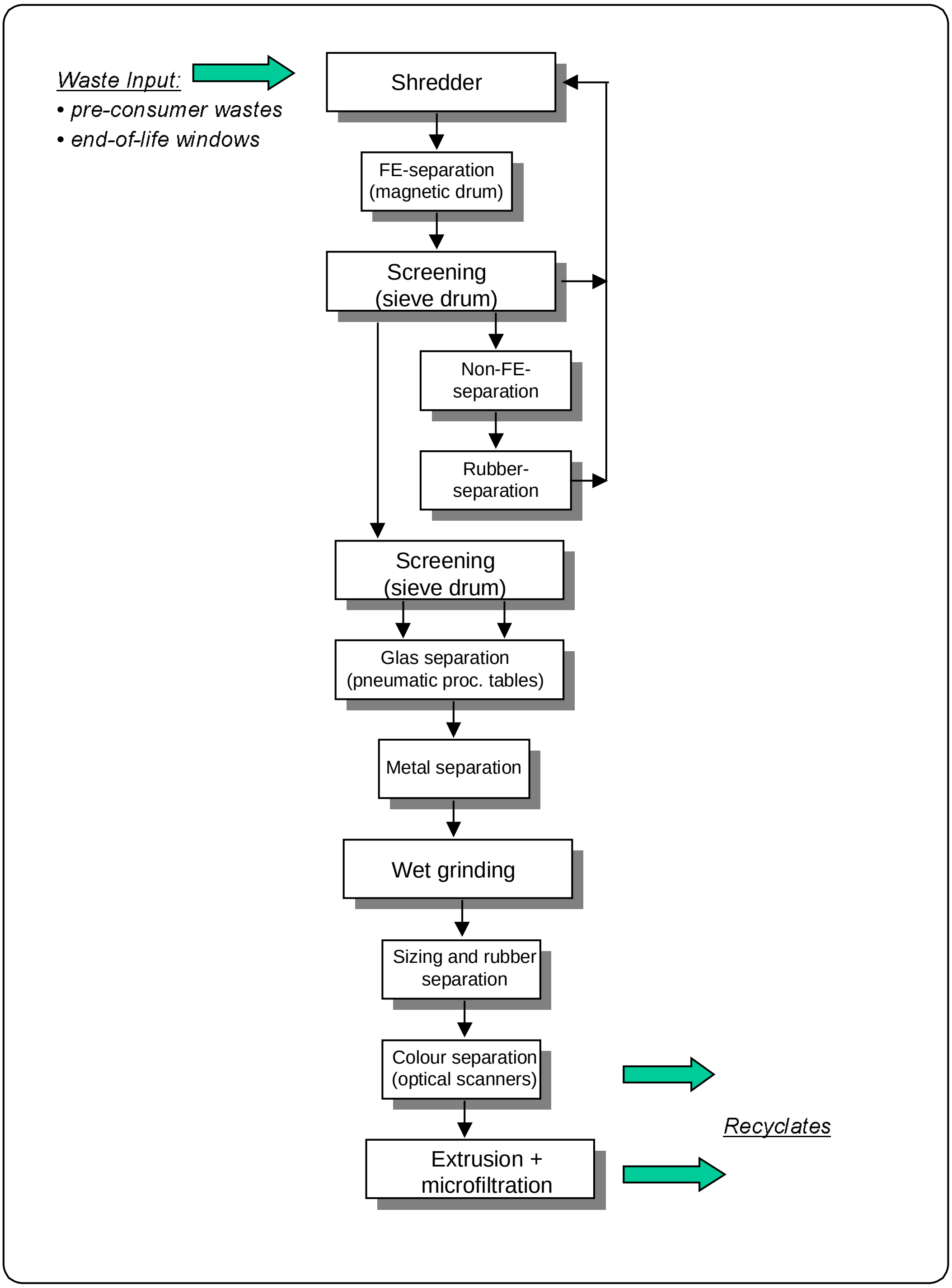
  Compared to this process the recycling plant of the **FREI** system is a "low-tech solution". A major part of the separation and sorting (dissassembling, separation of glass and rubber, separation by colours) is done manually. So the mechanical unit operations are restricted to shredder, grinding and metal separation before extrusion with microfiltration.

– **Capacities and quantities**: The utilisation of the recycling plants is dominated by pre-consumer wastes from the production and installation of window profiles:

- The **VEKA** plant has processed about 14.000 tons in 1998, of which only 4.000 tons where end-of-life windows (corresponding to about 2.000 tons of PVC compound). The capacity of the plant is 20.000 tons per year (after removal of bottlenecks).

- The **FREI** recycling plant is operating since 1984 with a capacity of 10.000 tons per year for the treatment of pre-consumer wastes; for the recycling of old windows a separate line with a capacity of 7.000 – 8.000 tons per year has been erected. The present utilisation is well below the capacity (according to Greenpeace 1997 at most 1.000 tons input in 1996).

Figure 3-5: Recycling Plant for PVC Window Profiles (VEKA)



- **Input material**: The input material is a mixture of pre-consumer and post-consumer wastes. Whilst the pre-consumer wastes are (more or less) pure PVC fractions (window profile cut-offs) the post-consumer wastes are PVC windows with or without panes containing rubber seals, metal profiles and fittings. The composition of the PVC material (content of additives) of the old windows is different depending on the profile producer and the production year.

- **Output material/recyclates**: Both recycling plants produce high-quality recyclates which can be used for the extrusion of new window profiles. According to the operator of the VEKA recycling plant, the differences in the composition of the PVC input (additives) does not give rise to quality problems of the recyclates.
  Theoretically it is possible to produce window profiles 100% from recyclates. However due to a reduced surface quality and the greyish colour of recyclates from the coloured PVC fraction - which limit their use in white profiles - the recyclates are used as a core in co-extruded profiles with a maximum share of 60 – 70% at the profile.
  Another issue is the content of toxic cadmium compounds in input material and recyclates, which were used as stabilizers in the past.

- **Geographical area:** Both the VEKA and the FREI system recycle material from all over Germany. There are also imports from the Netherlands and Austria.

- **Organisation:** Both the VEKA and the FREI system are voluntary initiatives of PVC profile producers. They are recycling organisations which have contractual agreements with the operators of recycling plants to ensure the recovery of the collected windows and with window producers (VEKA) or recyclers (FREI) to provide a collection system.

- **Financing:** In both systems the recycling costs are in principle borne by the waste owner who has to pay a fee of 25 DM per window to VEKA or 15 DM per window plus transport to the collection points in the FREI system or a cost-covering fee for a container service which transports the old windows directly to the recycling plants. Additional costs at the construction site (e.g. dismantling) must be paid by the waste owner too. However, due to guaranteed prices for the recyclates and/or by taking over deficits of the recycling plants, a part of the costs is covered by the recycling organisations.

- **Costs**: Exact cost calculations have not been made available by the recycling organisations or plant operators. Based upon information of the recyclers we estimate the order-of-magnitude of the present recycling costs as follows:
  - Transportation from the window producers (VEKA): 60 - 80 Euro/t
  - Treatment costs (VEKA): 350 - 400 Euro/t.

  So, the estimated range of **gross recycling costs is about 400 - 500 Euro per ton** of post-consumer windows. With achievable proceeds for recyclates in an order of 500 Euro per ton the estimated **net recycling costs are between 200 and 300 Euro per ton** of post-consumer windows (500 – 700 Euro per ton of recyclate output) depending on the material and the price for virgin PVC. Taking into account the present low prices for landfilling in Germany (50 - 150 Euro/t), the recycling of PVC windows is not competitive financially in most cases.

From the fees which are charged for old windows and the less extensive treatment technology, it can be estimated that the net costs of the **FREI** recycling system are lower than for the VEKA system. However, the FREI costs do not include the transportation costs to the centralized collection points.

3.3.2.4 Mechanical Recycling of PVC Pipes in the Netherlands

In the Netherlands the FKS association has been founded by the six national producers of plastics pipes (Draka Polva, Dyka, Martens, Omniplast, Viplex, Wavin) to organise the recycling of plastics pipes in the Netherlands.

– **Methods and Technologies:**

  - **Collection:** About 50 collection points have been set up all over the country where used pipes can be delivered free of charge. In parallel, rental containers have been installed at specific customers. Container rent and transportation costs are charged to the customer (about 100 Euro per ton on an average).
  - **Sorting and mechanical treatment:** There exists one recycling plant at the company Wavin (Figure 3-6). The mechanical treatment process consists of the following major unit operations:
    - → manual sorting line, there PP- and PE-pipes are separated from PVC pipes; this is possible due to the different colours (there is no labelling for different plastic types);
    - → shredder unit;
    - → separation units for rubber, Fe-metals and non-ferrous metals;
    - → sieve where sand and a coarse PVC fraction which is returned to the shredder are separated;
    - → extrusion to regranulates with microfiltration to remove residual contaminations.

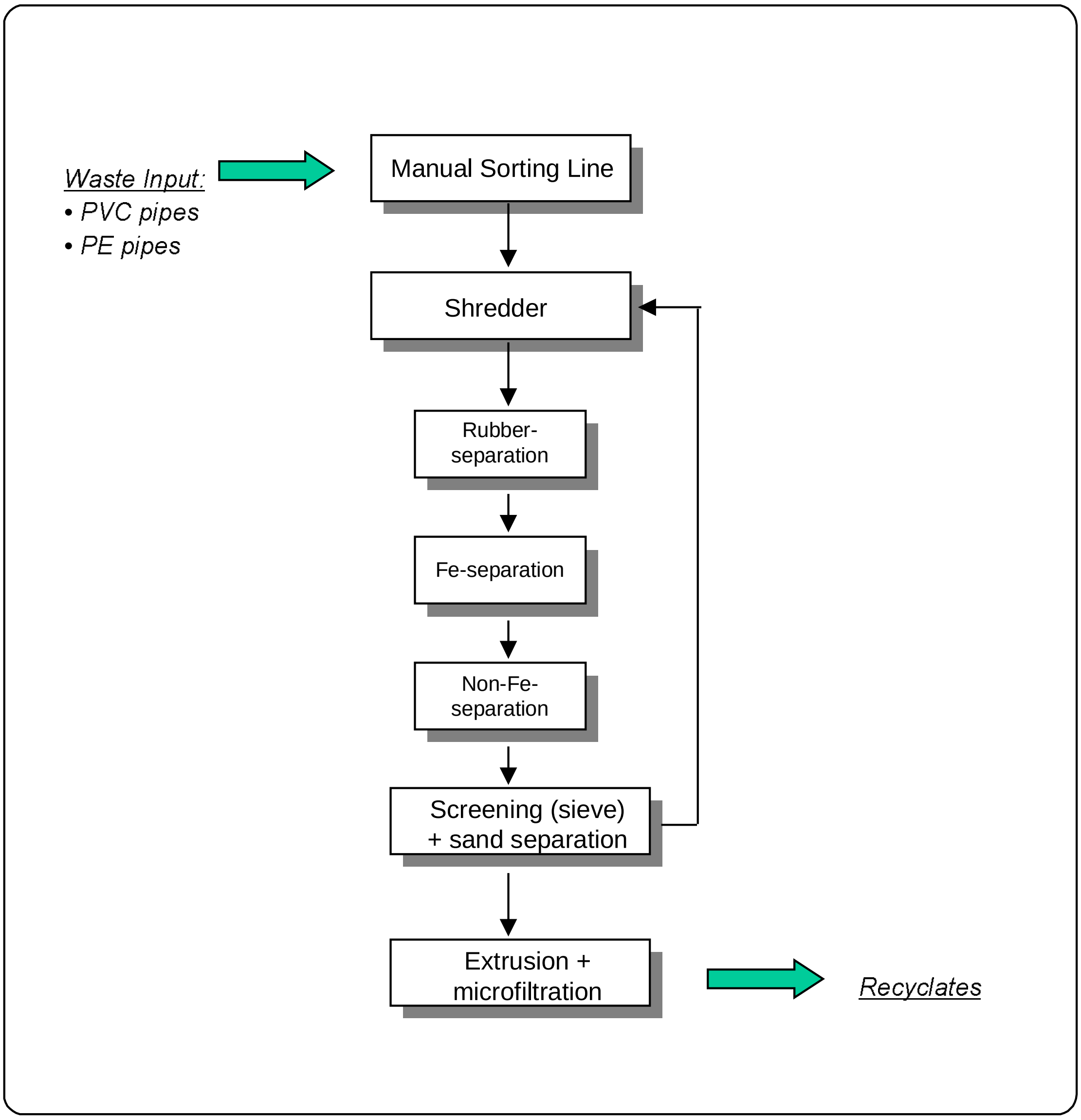
– **Quantities**: According to ECVM about 3.000 tons of PVC pipes have been recycled by the FKS system in 1996/1997. Due to the co-treatment with used PE and PP pipes as well as pre-consumer wastes, the capacity of the recycling plant is higher.

– **Input material**: The input material to the recycling plant is used plastics pipes (PVC, PE and PP) together with pre-consumer wastes (e.g. cut-offs). The contamination of this material is about 4%.

– **Output material/recyclates**: The recycling plant produces high-quality recyclates. In the Netherlands the recyclates can be used for the production of new multilayer pipes in a co-extrusion process where the recyclates constitute the middle layer in the pipe wall and the inner and outer layers are made of virgin PVC. In other countries like Germany the existing technical EN standards did not allow for the use of recyclates in

new pipes by now. Here, the recyclates are used in applications with low material standards, e.g. cable channels. However, the relevant standards are in the process of revision. In future, recyclates from used pipes and other products can be used for pipe production provided that the specification of the used materials is known. This is certainly the case for used pipes, but not necessarily for other plastics wastes.
A possible technical limitation for the use of the recyclates may be residual contaminations whose complete removal requires extensive technological measures (information of the German recycling organisation for pipes).

Figure 3-6: Recycling Plant for Plastic Pipes (Wavin)



– **Geographical area:** The recycling system covers the territory of the Netherlands. The average distance from collection points to sorting plant is approximately 150 km. However, also pipes from abroad are processed in the recycling plant.

– **Organisation:** The recycling system is a voluntary initiative of plastics pipe producers. The recycling organisation FKS is responsible for the logistics (operation of container depots, container rental, transportation via contracts with transport and container services) and has contractual agreements with the operator of the recycling plant to ensure the recovery of the collected pipes.

– **Financing:** The recycling costs f.o.b. centralised collection points are borne by the pipe producers via FKB. The waste owner has to bear the costs for collection and transportation to the central collection points or - if he makes use of the container system of FKB - he has to bear the costs for container rental and transportation.
Due to the very low quantities of end-of-life pipes compared to the production of new pipes, the financial requirements of the recycling system are still comparatively low for the pipe producers at present. However, with increasing quantities of post-consumer pipes the financial burden in relation to the turn-over for new pipes will increase.

– **Costs**: For the mechanical treatment of the plastics pipes the following cost figures have been reported:
  - Collection and logistics: 120 Euro/t
  - Treatment costs: 440 Euro/t.

  So, the **gross recycling cost is about 560 Euro per ton**. With achievable proceeds for recyclates in an order of 300 Euro per ton the estimated **net recycling costs are in the order of 250 Euro per ton** depending on the price for virgin PVC.

3.3.2.5 Mechanical Recycling of PVC Bottles in France

In the last years, PVC bottles have been successfully recycled in Europe. Provided a separate collection scheme exists, recycling is a profitable activity. The comparatively pure PVC fraction can be easily reprocessed. Since PVC bottles are collected together with other plastic bottles a sorting step is necessary to separate PVC from other plastics prior to reprocessing. In the last few years PVC bottles have been substituted by PET bottles to a large extent.

The responsibility for the French plastics bottle recycling scheme is shared by

- the municipalities, which ensure the collection and sorting within the MSW collection;
- Eco-Emballages SA, who provides the organisation;
- Valorplast, responsible for the transporting to the processing plant, the mechanical sorting and the recycling process. Valorplast is a subsidiary of SPMP and the Syndicat de Transformateurs (associations of PVC producers and transformers).

– **Methods and Technologies:**

- **Collection:** PVC bottles are collected together with other plastics bottles. The collection system is either a kerbside or a drop-off system depending on the municipality. Within this scheme, the bottles are brought to the sorting station, where they are manually sorted into HDPE, PET and PVC fractions.
- **Sorting and mechanical treatment:** Eco-Emballages (the organisation responsible for recovery and recycling of packaging wastes) provides Valorplast with the sorted PVC bottle fraction. Valorplast is responsible for the transport to the recycling plant near Paris. The bottles are sorted with X-ray technique in order to separate the remaining PET bottles. Then they are grinded and micronised.

– **Quantities**: Due to the substitution of PVC bottles by PET, the recycling quantities are decreasing and will amount to 3'000 t in 1999 (compared to 12'000 t in 1998 and 10'000 t in 1997). **In 2001, the facility will be closed**. The recycling plant has a capacity of 7'000 t.

– **Input material**: The input consists of an almost pure PVC bottle fraction from the separate municipal solid waste collection.

– **Output material/recyclates**: The recycling plant produces high-quality recyclates (PVC content: 99.9%). They are mainly used for the production of new multilayer pipes in a co-extrusion process where the recyclates constitute the middle layer in the pipe wall and the inner and outer layers are made from virgin PVC. The recyclates are also used to produce PVC profiles. Other applications include the production of compounds for shoe soles.

– **Geographical area:** The recycling system covers the French territory. There were two PVC bottle recycling facilities but one had to be closed due to the diminishing amount of PVC bottles to be processed. The remaining facility is located in Ile-de-France (Parisian Region).

– **Organisation:** Eco-Emballages SA organises the recycling of plastics, aluminium, tinplates as well as board and paper packaging. It provides the nationwide collection, sorting and recovery system for its members. Its shareholders are packaging manufacturers, retailers, industry and banks.

– **Financing:** The costs of Eco Emballage are covered by a fee on the packagings. The collected and pre-sorted bottles are provided to the recycling organisation Valorplast free of charge. The proceeds for the recyclates cover roughly the transport and processing costs of Valorplast.

– **Costs**: no data available.

3.3.2.6 Mechanical Recycling of PVC Floorings in Germany

In Germany the organisation ”Arbeitsgemeinschaft PVC-Bodenbelag Recycling” (AgPR) has been established by major producers of PVC and PVC floorings to recycle PVC floorings wastes. The systems exists since 1990.

– **Methods and Technologies:**

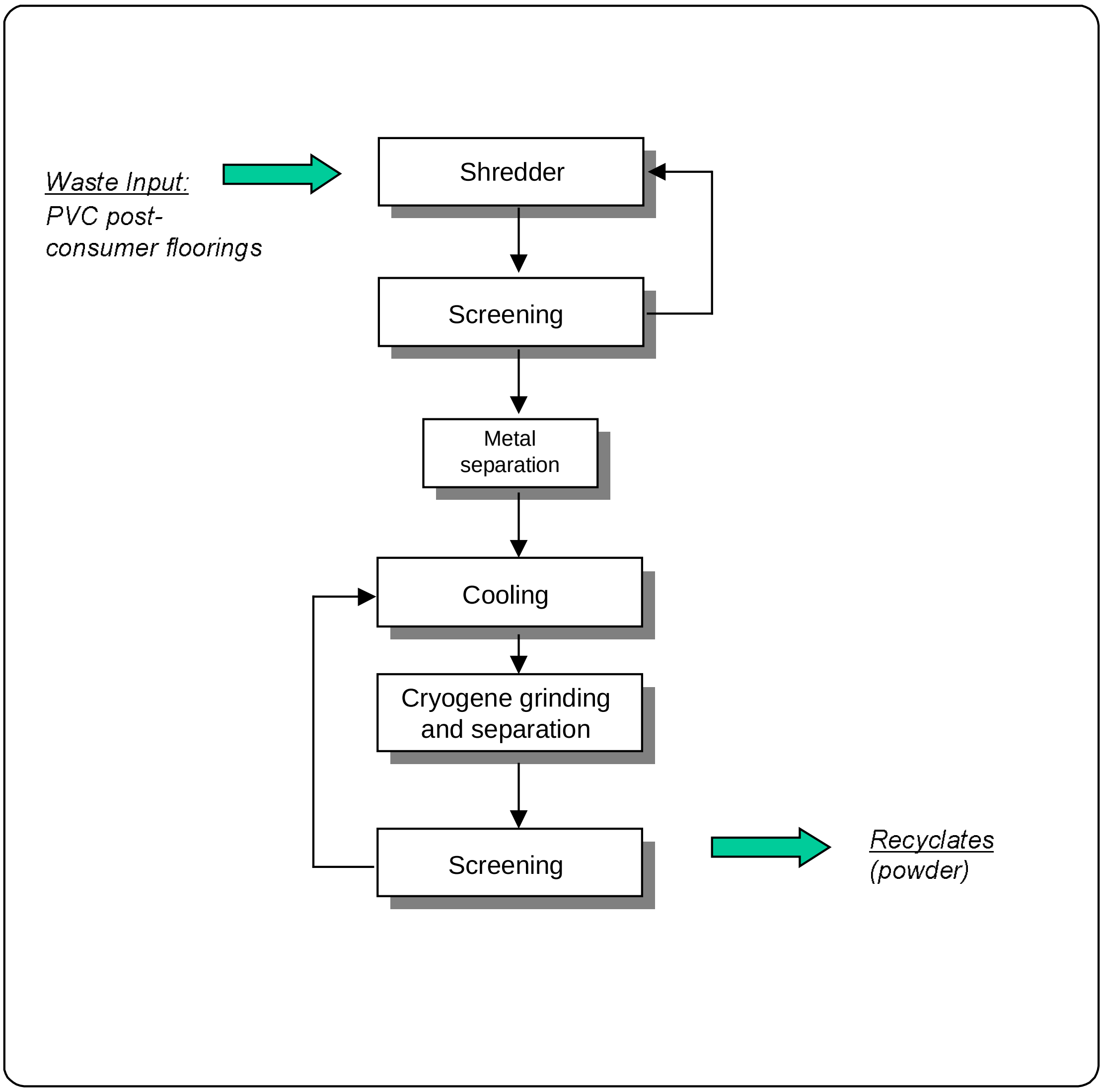
  - **Collection:** About 20 central collection points have been established where used pipes can be delivered. A fee of about 130 ECU/t is charged for the delivered material. The transport to the collection points has to be organised by the ”waste owner” himself. He has to bear the associated cost as well.
  - **Sorting and mechanical treatment:** For the mechanical treatment there exists one recycling plant which uses a cryogen (low-temperature) grinding process which allows for the grinding of flexible PVC material. It consists of the following major unit operations (Figure 3-7):
    → shredder unit;
    → screening unit where the coarse fraction is returned to the shredder unit;
    → metal separation;
    → cooling with liquid nitrogen
    → and subsequent cryogen grinding and separation;
    → screening unit where the coarse fraction is returned to the cryogen grinding and the fines constitute the recyclates which are homogenised and stored.

– **Capacities and Quantities**: Up to now the recycled quantities have been much below the capacity of the recycling plant: According to AgPU about 550 tons of (polymer) PVC have been recycled in 1998. This is equivalent to about 1’000 tons of PVC flooring material. The plant capacity is 6’000 tons per year.

– **Input**: The input material is used PVC floorings wastes. The major part of it is collected where larger lots arise, e.g. in renovation projects of warehouses. The material can contain considerable amounts of contaminations like glue or concrete which are difficult to separate from the PVC material.

– **Output material/recyclates**: The recycling plant produces high-quality recyclates. In the Netherlands, the recyclates can be re-used for the production of calandered PVC floorings in a separate backing layer. In Western Europe, about 40% of the PVC floorings are calandered products, the remaining 60% are made from PVC pastes which are not suitable as an application of the recycling material. Potential limitations for the use of the recyclates are residual contaminations (glue and mineral particles) which disturb the calandering process.

Figure 3-7: Recycling Plant for PVC Floorings (AgPR)



– **Geographical area:** The recycling system covers the territory of Germany. However, the collection points are very thinly distributed over the country, especially in the Eastern part. Therefore, considerable transport distances have to be bridged from the point of waste arising to the collection points and from there to the recycling plant which is located in the Western part of Germany.

– **Organisation:** The recycling system is a voluntary initiative of major producers of PVC and PVC floorings. The recycling organisation AgPR is responsible for the logistics (collection at the collection point and transport to the recycling plant) which is carried out by recyclers or waste management services which co-operate with AgPR and the mechanical treatment of the collected floorings in the recycling plant.

- **Financing:** The recycling costs are borne by the waste owner who has to pay a fee of about 130 Euro f.o.b. centralised collection points. A part of the recycling costs is borne by the owners of the recycling system by subsidies on the selling price of the recyclates produced or by covering the deficits of the system. The fee raised at the collection points covers the net (subsidized) costs for transport and recycling (costs minus proceeds for recyclates). The waste owner has to bear the costs for the separate collection at the construction sites and the transportation to the collection points.

- **Costs**: We estimate the order-of-magnitude of the present costs for the recycling of PVC floorings (at full utilisation of the plant capacity) as follows:
  - Transportation to the collection points: 50-100 Euro/t
  - Transportation from the collection points: 50 Euro/t
  - Treatment costs: 350-350 Euro/t

  So, the estimated **gross recycling cost ranges from about 400 to 500 Euro per ton** of post-consumer flooring. With achievable proceeds for recyclates in an order of 100-150 Euro per ton, the estimated **net recycling costs are between 300 and 400 Euro per ton** approximately, depending also on the price for virgin PVC.

3.3.3 Impact of PVC on the Recycling and Recovery of Plastics and other materials

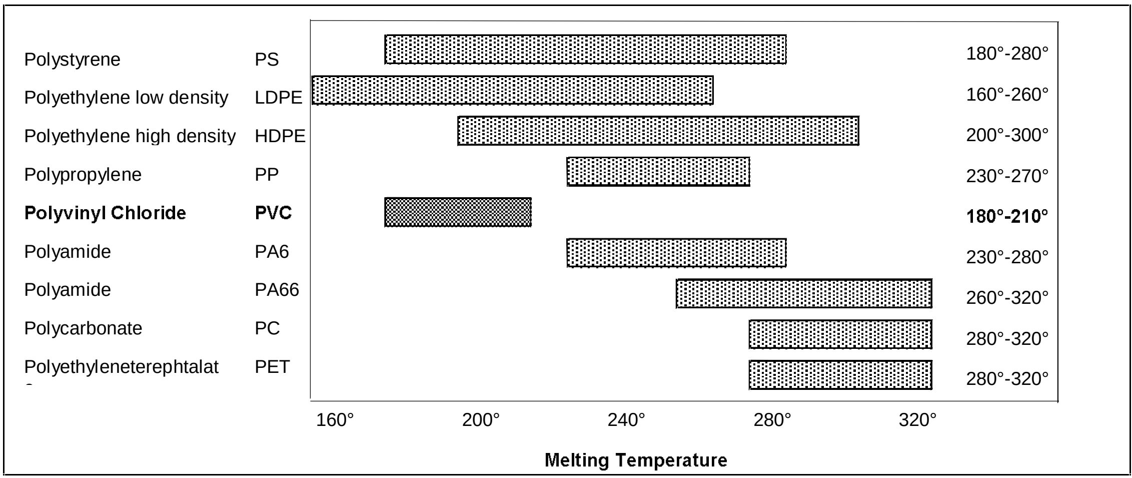
(1) In the recycling of mixed plastics wastes (containing also PVC) only metals and stony material is separated before the process to avoid abrasions and damages of the shredder and the grinder. After shredding and grinding, the agglomerated or just grinded mixed plastic is plastified in an extruder. When assessing the impact of PVC in mixed plastics recycling processes two cases must be distinguished:

- the recycling of plastics wastes with a low PVC content and
- the recycling of „PVC-rich“ plastics wastes.

(2) In practice the most important materials in mixed plastics fractions are polyolefins (PE and PP esp., e.g. in plastics packaging wastes). The achievable quality of the products of the mixed plastics recycling depends on the melting temperature, on possible chemical reactions and on the rheological properties (flowing properties) in the extruders. PVC has a comparatively low processing temperatur with a narrow „temperatur window“ (Figure 3-8). If the processing temperature of PVC is exceeded, hydrochloric acid (HCl) is released, material structures can be destroyed, and the risk for corrosion of the facilities (especially in the extruder) increases.

As a consequence, in the recycling of mixed plastics fractions with **low PVC contents** the polyolefin content must be at least 70%, in order to avoid that the PVC disturbs the processing and degrades the material quality. To avoid these negative impacts the HCl can be absorbed with lime or limestone. However, if the PVC content is small (e.g. less than 5% like in packaging wastes) in most cases a dehydrogenation unit is installed prior to the extrusion where the chlorine is removed in a thermal and chemical process.

Figure 3-8: Processing temperatures of mass plastics (from Möller/Jeske)



In the processing of **plastics fractions with a high PVC content** and limited amounts of other plastics the processing temperature of the mixed fraction must be in the range of pure PVC processing, i.e. 180 -210°C. Since they provide more flexible „temperature windows“ than PVC polyolefins do not disturb the processing of these PVC-rich fractions in the same way as PVC disturbs the recycling of polyolefin-rich fractions as described above.

However, the presence of PET and rubber disturbs the extrusion process of PVC-rich plastics fractions resulting in a poor product quality.

As a conclusion it can be maintained that the processing of PVC together with other plastics is generally possible. However, normally this co-processing will lead to a lower quality. In mixed plastics fractions with low PVC contents PVC disturbs the co-processing, requiring additional measures where PVC or chlorine is removed from the process. Due to this fact it seems to be questionnable to speak of „PVC recycling“ for this case. However, the related PVC quantities (e.g. PVC in packagings) are usually included in the recycling balances for PVC (including the figures given in Chapter 3.1 above).

(3) In addition to mixed plastics wastes PVC can disturb the treatment and recycling of **other wastes** too. PVC can contribute to the formation of dioxines in thermal waste treatment processes, especially in the presence of metals. An example is the recycling of **metal scraps** e.g. from car shredder plants which can result in dioxine formation if the metal is coated with PVC (e.g. underground protection of cars).

4. Assessment of PVC Recycling: Limits and Potentials

(1) Based upon the experiences with existing PVC recycling systems (chapter 2) and the general considerations concerning the future development of PVC waste quantities and PVC recycling (chapter 3), the general potentials and limits of PVC recycling can be determined. This is done in the following chapters 4.1 to 4.3. The analysis is carried out in two steps:

- In the first step the technical **recycling potentials** are assessed by product group, based upon practical experiences with recycling schemes in general. The recycling potential is the maximum PVC quantity which can be recycled under practical conditions, i.e. taking into account the available collection systems as well as sorting and separation technologies.

- In the second step it will be discussed to which **extent** these technical potentials can be **realised in practice**, taking into account the economic and environmental limits experienced in existing PVC and plastics recycling systems.

(2) The major factors limiting PVC recycling are at the same time the starting-points for measures to improve PVC recycling. These are developed in 4.4.

4.1 Technical Potentials for Mechanical PVC Recycling

(1) As mentioned above, the technical potential of mechanical PVC recycling refers to the maximum achievable PVC quantity under practical conditions. This represents not strictly a technical potential, but economic aspects are taken into consideration too: technical solutions which involve excessive costs, for example the separation of PVC from mixed waste streams with very small PVC contents (smaller than 5 - 10%) in sorting plants, are not included. One example is PVC in mixed packaging wastes, where PVC is not sorted out as a seperate fraction but recovered together with other plastics in a mixed fraction.

The assessment of these technical potentials is based upon the general considerations concerning the development of PVC waste quantities (Chapter 2) and the experiences with recycling schemes in general and the existing PVC recycling systems in particular (Chapter 3).

(2) When determining the technical recycling potential one important point must be stressed:

– **The recycling potential depends on the quality of the recyclates to be achieved.**

So, in accordance with the general considerations developed in Chapter 2.2.2 two types of mechanical PVC recycling can be distinguished:

1. **"High-quality recycling"** yielding recyclates which can be re-used in the same PVC applications (taking into account the general limitation of a 1:1 substitution of virgin PVC discussed in 2.2.2) and

2. "Low-quality recycling" or **"downcycling"** yielding mixed materials of different types of PVC or different types of plastics.

For both types of PVC recycling the recycling potential depends on the **potentials to separate** a pure PVC, mixed PVC or mixed plastics fraction respectively by separate collection, subsequent sorting or subsequent mechanical treatment.

(3) In the following sections the recycling potentials for both "high-quality" and "low-quality" mechanical PVC recycling will be assessed product group by product group applying the following general **procedure**:

- First the product or waste groups which are suitable for mechanical recycling will be determined based upon the potentials to separate out PVC fractions of an appropriate purity from the related waste streams.

- Secondly, the potential recycling rates (percentage of PVC waste arising which can be recycled mechanically) will be determined by estimating the achievable collection rates and (in case of "high-quality" recycling) the achievable absorption rates for recyclates in the different products.

- Thirdly, the recycling quantity must exceed a certain minimum to be able to operate recycling plants of feasible sizes.

4.1.1 Technical Potentials for "High-quality" PVC Recycling

(1) High-quality recycling is applicable for those product groups only there a **pure PVC fraction of a sufficient quantity** can be separated; this may be by separated collection, subsequent sorting or subsequent mechanical treatment.

When checking this for the different PVC waste groups a first important distinction has to be made between pre-consumer and post-consumer wastes:

- **Pre-consumer wastes** (production wastes or installation wastes like cut-offs) are suitable for mechanical recycling for more or less all PVC product groups: At least a part of the pre-consumer waste arising in most product groups can be returned to the processors and re-used directly without major sorting or pre-treatment. The main exceptions are PVC applications in the areas of coatings, organosols and plastisols where processing wastes are no more available for mechanical recycling.

- As for **post-consumer wastes**, only a part of them can be separated. The following product or waste groups especially cannot be regarded as candidates for high-quality recycling:
  - **composite materials**, applications of PVC pastes especially: For products like paste based floorings, wall coverings, car underfloor protection, artificial leather or coatings, the separation of the plastics content by mechanical treatment is not feasible. The same holds for composite products like furniture films or multilayer packaging films. Chemical processes like the "Vinyloop" process mentioned in Chapter 1 may be qualified to recover this PVC waste. However, these processes are not included in the scope of this study.
  - **mixed post-consumer plastics fractions** from which PVC in an appropriate quality cannot be separated with the existing technologies: this applies to PVC from the recycling of cables, electric/electronic appliances and cars. In the mechanical treatment processes of these products (shredding with subsequent separation of different material fractions) PVC is recovered mixed with other plastics or materials. In packaging and other product groups like health care products, the separation of pure PVC is not feasible, due to the low PVC content (far below 10%) in the related waste streams.

(2) As a **lower limit** to "high quality" recycling an EU-wide quantity of **20'000 tons per year** (output of PVC recyclates from pre-consumer and post-consumer wastes on a compound basis) seems to be reasonable: For technical reasons (size of the equipment) and economic reasons (increase of costs beyond a sensible limit), there is a minimum capacity of a recycling plant (mechanical treatment) including the collection and logistic system, which we estimate at about 5'000 tons per year. 20'000 tons of recyclate output per year means that at least in each of the four Member States with the highest PVC waste arisings, Germany, Italy, France and the UK, the operation of one recycling system with 5'000 tons output per year would be feasible.

The different PVC product/waste groups have been screened roughly for this criterion: Since total PVC waste arisings form an upper limit to the recycled quantities, product/waste groups with a total waste arising lower than 20'000 tons in the considered period have been excluded as candidates for a high-quality post-consumer recyclate. The basis for this screening is the estimated PVC waste arisings which are described in Chapter 5.1 below.

PVC POST-CONSUMER WASTES WITH A POTENTIAL FOR MECHANICAL RECYCLING

(3) Based upon these criteria, the major part of PVC **pre-consumer wastes** has a potential for mechanical recycling (see Table 4.1 and Appendix A.1).

Table 4.1: Recycling and absorption potentials of the major[12] PVC product/waste groups suitable for high-quality mechanical recycling

PVC product/waste group	Potential recycling rate (%)		Potential absorption rate[a)] (%)
	Pre-consumer wastes	Post-consumer wastes[b)]	
1. Construction products			
Flooring calandered (F)	40	20-30 (25)	30
Profiles and hoses (F)	50	15-25 (20)	20
Pipes (R)	50	60-70 (65)	35
Window profiles (R)	75	50-60 (55)	45
Profiles – cable trays (R)	75	30-50 (40)	40
Other profiles (R)	55	30-50 (40)	30
2. Packaging products			
Bottles (R)	90	35-45 (40)	–
3. Furniture components	10-35[c)]		0-5
4. Other consumer and commercial products			
Shoes, soles (F)	90	15-25 (20)	35
Miscellaneous (F)	90	5-15 (10)	–
Printing films (R)	80	30-40 (35)	–
Sheets, chemical equipm. (R)	80	30-40 (35)	30
Miscell. sheet products (R)	70	20-40 (30)	30
Miscell. rigid profiles (R)	75	10-20 (15)	10
Other rigid products (R)	90	10-20 (15)	10
5. Electric/electronics	10-90[c)]	–	0-10
6. Automotive	15-90[c)]	–	0-10
7. Other Products	65-75[c)]	–	–

F = Flexible PVC applications; R = Rigid PVC applications

a) related to post-consumer wastes

b) in brackets = chosen rates

c) absolute quantities are low; range of recycling rate depending on the product group

d) This recycling rate refers to the quantity of used pipes which actually arises as **waste**. It must be taken into account that the major part of used PVC pipes remains in the ground (approximately 70%). This means that the recycling potential related to the total quantity of used pipes is about 20% only.

12) The table contains those product/waste groups with a total recycling potential of more than 20'000 tons per year (pre-consumer plus post-consumer wastes) only. The recycling potentials of all PVC product groups are shown in Appendix A.1.

The set of potential **post-consumer PVC wastes** is much more limited. It comprises the following groups:

- The high-volume **construction products** are specifically suitable for recycling since they allow for comparatively favourable logistical conditions, i.e. they can be collected separately or separated in sorting plants for construction wastes. For floorings, pipes and window profiles, recycling systems with separate collection already exist in some EU Member States (see Chapter 3.3). Additional high-volume candidates are other rigid profiles (cable trays and shutters especially) as well as flexible profiles and hoses. The other high-volume construction products are not suitable for high-quality recycling: floorings produced from PVC pastes and wall papers are composite products and cable insulation wastes are mixed plastics wastes (see above). By now the re-use of recyclates from pipe recycling for the production of new pipes is limited by technical standards (see Chapter 3.3.2.4). These standards are however in the process of revision in order to lift these restrictions. Thus we expect that the high-quality recycling of pipes will be possible before 2005.

- In the group of **consumer and commercial products** (packaging products, furniture components, other consumer and commercial products) there is a large number of composite products (e.g. coating applications like artificial leather, organosol and plastisol applications or furniture components) and low-volume PVC applications which are not suitable for high-quality mechanically recycling. However, there is still a number of potential candidates remaining. Most of these products arrive at municipal solid wastes or packaging wastes collections by now. If they are to be recycled mechanically, it will not be feasible to have specific collection systems for PVC or the related PVC products respectively, but the collection will be organised for the related product-groups as a whole, together with other materials. The existing collection systems for packaging (separate collection of plastics or "light" packaging wastes) are examples for such systems. To achieve high-quality recyclates PVC must be sorted out in sorting plants or separated in mechanical treatment processes subsequently. The feasibility of these operations depends amongst others on the PVC content of the collected waste fractions. If it is too low, feasibility cannot be achieved. Therefore, at least for some of the product groups the recycling potentials will be limited due to the low PVC contents in the collected wastes. This is especially true for plastics **packaging** collections where polyolefins (PE and PP) are the dominant polymers and PVC packaging films are of minor importance (although constituting a significant PVC waste stream). The only packaging products suitable for high-quality recycling are PVC bottles in some Member States. They are collected together with PET bottles with subsequent separation of a pure PVC material fraction. However, PVC bottles are increasingly substituted by PET, so that a gradual phase-out of the PVC bottle recycling activities is expected. For the recycling of the **non-packaging** PVC candidates, separate plastics collection systems (with subsequent separation of the polymers) are a potential solution. Waste streams from commercial and industrial sources are concerned here (printing films and sheets especially). Another potential waste stream is used footwear. A potential solution for their recycling is through collection systems for used textiles and clothes where PVC shoes can be sorted out as a separate fraction.

- The present practice of the recycling of **electric/electronics** and **cars** is a mechanical treatment: After limited dismantling operations to remove hazardous substances or reusable components, the end-of-life products or vehicles respectively are shredded and in subsequent separation operations different material fractions are separated. For economic reasons the separation aims at the recovery of the metals mainly, whilst plastics end up in mixed fractions which are landfilled or incinerated to a large extent (shredder residues in the case of car shredders and mixed plastics fractions with contaminations in the case of electronic scrap recycling). So, the high-quality mechanical recycling of PVC in these products is limited to the pre-consumer wastes arising in pure fractions.

- For the remaining **other products** (medicine and agriculture) waste arisings are too low to allow for a feasible operation of a PVC recycling system.

POTENTIAL RECYCLING RATES

(4) Table 4.1 includes also the estimated potential recycling rates for high-quality mechanical recycling.

The potential recycling rates for **pre-consumer wastes** recycling have been oriented at the present recycling practice.

The estimates for **post-consumer wastes** recycling are based upon ”best guesses” which have been elaborated in a number of discussions inside the PVC industry including PVC producers, PVC converters and recyclers. These industry estimates have been cross-checked in discussions with ECVM and EuPC and with the results of related studies (GUA 1998, TNO/Sofres 1998) including also former Prognos studies (Prognos 1994).

The potential recycling rates are the results of the combination of

– the potential **collection rates**, i.e. the percentage of the total waste arising per product group which can be separated from the related mixed waste streams (e.g. municipal solid wastes, mixed construction wastes) by separate collection systems; this can be either product-specific collection systems where PVC is collected together with other materials (like in the case of packaging waste), or PVC-specific collection systems (like in the case of windows);

– the potential percentage of the PVC quantity contained in the separately collected wastes which can be **separated as a pure PVC fraction** (suitable for high-quality recycling); PVC fractions which cannot be separated in sorting or mechanical treatment processes as well as material losses in the recycling processes (sorting, mechanical treatment) are subtracted here.

(5) As a matter of course, for **pre-consumer wastes** higher recycling rates can be achieved than for post-consumer wastes.

- **High recycling rates** of more than 70% can be achieved in those product groups where production wastes constitute the major part of the pre-consumer wastes, e.g. in the cases of bottles, shoes/soles or injection moulding components for cars or electronic devices.

- **Lower recycling rates** of less than 70% can be achieved in those product groups where cut-offs from the installation of the products form the major part of the pre-consumer wastes; here PVC is contaminated, a component of a composite product or mixed with other wastes. This applies e.g. for the major part of the building products.

(6) The potential recycling rates for **post-consumer wastes** range from 5% to 70% depending on the product group. The estimates for some important waste groups can be commented on as follows:

- For **floorings** the achievable collection rate can be considerably high (about 80% of waste arising) taking into account the experiences with similar separate collection systems. The material can be discarded separately in containers at the construction sites. However, only a limited percentage of that (in the order of 30%) can be recycled to high-quality recyclates, due to contaminations like glue, sand or concrete. Thus the potential overall recycling rate is reduced to about 20-30%.

- For **pipes and fittings** the estimated potential recycling rate is 60-80%. This figures refers to the quantity of used pipes which actually arises as waste. This is only a part of the total quantity of worn-out pipes (estimated 30%), whilst the major part is left in the ground for cost reasons (unless the old pipes are replaced by new ones at the same location). Therefore, compared to the total quantity of used pipes the recycling rate would be 20-25% only. It can be expected that the collection of PVC pipes will be organised together with other plastics pipes like PE, as it is practised in the existing recycling systems. Thus, a subsequent sorting process is necessary to separate the PVC from the other plastics. Due to the size of the collected parts and different colours the separation is comparatively easy to manage. This results in comparatively high potential recycling rates, taking also into account losses in collection (about 20%), sorting (about 10%) and mechanical treatment (about 10%).

- Also for **window profiles** comparatively high recycling rates (50-60%) can be achieved: The conditions for collection are favourable like in the case of flooring, resulting in an estimated potential collection rate of 80%: Old windows can be returned by the window producers when old windows are replaced by new ones (renovation) or dismantled and kept separately in demolition projects. Of the collected window profiles 60-70% can be recycled to high-quality recyclates, taking into account that the mechanical recycling process requires extensive separation operations (rubber, metals, glass, sorting by colours, etc.).

- Based upon the experiences with existing packaging recycling systems, the potential collection rate for **PVC bottles** can be in the order of 80% (in mixed collection systems). Also based on the existing experiences we estimate that 50% of this quantity can be recycled to high-quality recyclates, taking into account the sorting and mechanical treatment processes.

- For PVC in **households or commercial wastes**, like book covers, bags, camping articles and shoes, only mixed collection systems are feasible with subsequent sorting and mechanical treatment (see above). Therefore, for some products considerable collection rates at or above 50% can be achieved. This applies for PVC in commercial wastes (office supply, printing films, sheets) especially, which arise in sufficiently large charges to make a separate collection feasible (e.g. together with other plastics wastes). Also for some consumer product wastes arising in considerable quantities (footwear especially) existing or new collection systems (e.g. textile collections) with subsequent separation of the PVC products are feasible. However the yield of high-quality recyclates in sorting and mechanical treatment processes will be comparatively low, resulting in overall potential recycling rates between 10 and 20% only.

- In the remaining product/waste groups the recycling potentials are limited to a few candidates only.

(7) Table 4.1 includes also the estimated **absorption rates** which specify the maximum percentage of recyclates which can be used for the production of the related products as substitute for virgin PVC.

These estimates have been provided by EuPC based upon information from PVC converters. They have been checked with available information (for the material composition of available pipes and profiles with recyclate layers).

CORRECTION BY LOW-VOLUME WASTE GROUPS

(8) As fixed above a quantity of about 20.000 tons per year (PVC output from the recycling systems) has been defined as a limit for a feasible PVC recycling. With the potential recycling rates and the projected development of total waste arising described in Chapter 5.1 those product/waste groups have been eliminated from the list of potential candidates for

high-quality recycling where the achievable quantities are below 20.000 tons per year.[13] The detailed list of the resulting recycling potentials is shown in Appendix A.1.

4.1.2 Technical Potentials for ”Low-quality” PVC Recycling (Downcycling)

(1) ”Low-quality recycling” refers to the mechanical recycling of PVC in mixed plastics waste fractions. It can be applied for those types of PVC wastes where high-quality recycling is not feasible but a collection and recycling together with other PVC or plastics materials is possible. This requires that the total waste arising in the related product groups reaches a minimum quantity to make a separate collection feasible or that the mixed plastics fraction can be collected in a ready-to-process quality, so that sorting or mechanical treatment is not necessary.

When checking this for the different PVC waste groups the following waste groups candidates have been identified for low-quality recycling:

- The first group is constituted by the remaining **pre-consumer wastes** which cannot be recycled in a high quality. For most of the pre-consumer wastes, a separate collection is feasible, for example in the frame of general systems or business activities for plastics waste management and recycling for industry and commerce like they exist in some Member States. The achievable recycling rates depend on the origin of the pre-consumer wastes: **Production wastes** are easier to collect reaching an estimated potential recycling rate of 70% (taking into account collection, sorting and treatment efficiency). For **installation wastes** (e.g. cut-offs from the laying of floorings or cables) the separate collection requires more efforts, e.g. on construction sites where a number of different containers for the different waste fractions to be separated must be installed, the personal must be trained, etc. Therefore the willingness for waste separation is lower and a lower potential recycling rate of 50% seems to be realistic for these wastes. Installation wastes in applications of PVC **plastisols, organosols and coatings** are not suitable for mechanical recycling, due to the composite structures. This concerns e.g. a part of PVC floorings.
  The estimated recycling rates for the pre-consumer wastes are shown in Table 4.2. For those product groups where pre-consumer wastes are composed of both production wastes and cut-offs, the average potential recycling rate is given, taking also into account that depending on the waste group a part of total pre-consumer waste arising can be recycled to high-quality recyclates (see 4.1.1).

13) This screening procedure applies for pre-consumer and post-consumer wastes only where a sorting and/or mechanical treatment is necessary to recover high-quality recyclates. For some pre-consumer wastes (production wastes especially) which can be directly re-used by the PVC processors without further treatment it has been assumed that there is no quantitative limit for recycling.

Table 4.2: Recycling Potentials of the major[14] PVC product/waste groups suitable for low-quality mechanical recycling

PVC product/waste group	Potential recycling rate (%)	
	Pre-consumer wastes	**Post-consumer wastes**[a)]
1. Construction products		
Cables (F)	60	70-90 (80)[c)]
Flooring calandered (F)	55	–
Pipes (R)	45	–
2. Packaging products		
Rigid films (R)	25	15-25 (20)
3. Furniture components	60[b)]	–
4. Other consumer and commercial products		
Credit cards (R)	90	–
5. Electric/electronics		
Cables (F)	70	30-50 (40)
Adhesive tapes (F)	15	30-50 (40)
Inject. moulding parts (F)	–	30-50 (40)
6. Automotive	60-90[b)]	–
7. Other Products	0-30[b)]	–

F = Flexible PVC applications; R = Rigid PVC applications

a) in brackets = chosen rates

b) absolute quantities are low; range of recycling rate depending on the product group

c) This recycling rate refers to the quantity of used cables which actually arises as **waste**. It must be taken into account that the major part of used cables remain in the ground (approximately 70%). This means that the recycling potential related to the total quantity of used cables is about 25% only.

- In the group of **post-consumer wastes**, the following PVC product groups are feasible for low-quality recycling:
  - **Cables (domestic applications)**: The low-quality recycling of cables is one of the major areas of PVC recycling today. The recycling of post-consumer cable wastes is carried out together with cut-offs from the laying of cables. PVC is included in the mixed plastics fraction output from the cable recycling plants which can be readily used for the extrusion of piles, traffic control systems, etc. The estimated potential recycling rate is about 70-90%. This recycling rate refers to the PVC in **collected** cables arising as wastes. Like in the case of pipes, the major part (about 70%) of the worn-out underground cables are not dismantled or extracted from the ground for economic reasons. Therefore, if the recycling rate is related to the total amount of worn-out cables it results a figure of 20-25% only. The estimate of the reycling rate takes account of material losses in the

14) The table contains those product/waste groups with a total recycling potential of more than 20'000 tons per year (pre-consumer plus post-consumer wastes). The recycling potentials of all PVC product groups are shown in Appendix A.2.

cable shredding and waste flows into alternative waste management options for the mixed plastics fraction (feedstock recycling, energy recovery).

– **Packaging wastes (rigid and soft films)**: PVC in packagings is or will be collected together with other packaging materials. From the experiences with the existing recycling systems in Germany and Austria especially, the achievable collection rates are in the order of 80%. However, in the subsequent sorting and mechanical treatment processes considerable losses occur: Since the PVC content of the plastics collections is low the separation of PVC or PVC rich fractions in sorting plants is not feasible. Hence the PVC ends up in the sorting residues (which are landfilled or incinerated) or in mixed plastics fractions. Taking into account that a part of the mixed plastics fraction will go to energy recovery and feedstock recycling we estimate that at most 20-30% of the PVC in packaging collections can be recovered for low-quality recycling. Hence, the estimated overall recycling potential for PVC in packaging wastes is about 15-25%.

– **Other household and commercial wastes**: The recycling of PVC in non-packaging applications from household wastes will not be feasible, due to low quantities (compared e.g. to packaging wastes) and/or the appearance of plastics in composite products (e.g. in the case of films for furniture). Only those PVC products which end up in commercial wastes and whose collection can thus be integrated into separate mixed plastics collections for commerce/industry are potential candidates for low-quality mechanical recycling. Hoses, technical applications of rigid films (office supply, printing films, others), and a part of the miscellaneous product groups are concerned here. The potential recycling rate has been estimated at 30%. For applications which are used in both industry/ commerce and households this rate has been reduced to 15%.

– **Electric/electronic wastes**: On an EU level and in several Member States regulations for enforcing/improving the recycling of electric/electronic wastes are in preparation. The recycling potentials are considerably high. The technological state-of-the-art for the recycling of electric/electronic products is the mechanical treatment, where the PVC components are recovered in a mixed plastics fraction – similar to cable recycling. Just like for cable recycling there is a potential to use this material for the extrusion of different products with low material specifications. According to the experiences with a number of collection and recycling schemes for electric/electronic wastes and related pilot projects, the achievable collection rates (in relation to the estimated waste arising) are in the order of 50%-60% (Prognos 1998). Based upon these experiences and taking into account losses in the mechanical treatment process (in the order of 10%) the maximum overall recycling rate for the PVC components is about 50%.

For PVC in **end-of-life vehicles** we do not expect any significant mechanical recycling. As mentioned before, there may be a limited dismantling before shredding allowing for a limited high-quality PVC recycling but the major part of the PVC will still be contained in the shredder residues. According to the regulations in preparation, these residues will have to be recovered to a large extent. However, according to the present technological development, mechanical processes which allow for the material recovery of PVC and other plastics from the shredder residues will not be applied. In contrast to the plastics fraction from electronic waste shredding, the mechanical separation of plastics from car shredding residues requires a subsequent treatment for which technical solutions are not straightforward, lacking economic competitiveness too. Therefore, most probably energetic treatment processes will prevail, where the plastics content is used for energy recovery.

4.2 Limits to the PVC Recycling Potentials

4.2.1 Environmental Limits

(1) The general environmental limits of PVC recycling have been already discussed in Chapter 2.2.2. Two major limits are relevant:

1. **no life cycle improvements**: If the recycling of the related PVC products provides no or no significant environmental savings (resource consumption, emissions into air and water, wastes) as compared to disposal, incineration or energetic/feedstock recovery, there is no justification for promoting PVC recycling (except in those cases where it provides economic advantages).
2. **potential toxicological risks:** The dispersion of toxic heavy metal stabilizers in the PVC (cadmium and lead) into the products made of the recyclates and the possible contamination of cable scraps with toxic PCB involve potential health and ecological risks.[15]

(2) Based upon these limits the following **conclusions** can be drawn concerning the utilisation of the technical potentials of mechanical PVC recycling:

1. Based upon the results of life cycle assessment studies for plastics waste management (see 2.2.2 above) the environmental benefits of "low-quality" mechanical plastics recycling must be regarded as low. As a consequence, **the technical potential for "low-quality" PVC recycling** (see 4.1.2) **is uncertain**, since the environmental justification is weak.

   However, low-quality mechanical recycling can be justified for **economic reasons** in some cases. This applies for the "low-quality" mechanical recycling of most pre-consumer wastes as well as post-consumer cable insulation wastes which can be recycled

15) **Phthalates** and some **chlorinated parafines** which are used as plasticizers are being regarded as critical for their ecological and health effects as well. A phase-out of certain plasticised PVC applications would of course result in a phase-out of the recycling of plasticised PVC as well (e.g. cables, floorings). In the ongoing international evaluations and discussions some EU Member States have banned the use of phthalates in certain toys and child care articles and there are some official institutions which recommend a phase-out of plasticised PVC, like in Sweden (Ecocycle 1994), Denmark and Germany (UBA 1999). However, considering the present state of discussions there seems to be no consensus for a general ban on plasticised PVC.

at competitive costs. The same can be expected for the mixed PVC/plastics fraction from the mechanical treatment of electric/electronic scrap (see 4.2.2). In contrast, the recycling of **mixed packaging wastes** is not viable economically, for it involves excessive costs (see below).

2. As mentioned in 2.2.2 there are different points of view on the **toxicological issue**.

   As a matter of fact, **cadmium and lead** are toxic and persistent substances. However, one part of experts argue that the actual risk of an exposure of humans and the environment to these substances is comparatively low: The lead and cadmium compounds are fixed in the PVC matrix. A release is not possible but potentially in landfills (eluation) and in case of accidents in waste handling areas, incineration plants or fires. Not only the likelihood of such occurrences is comparatively low but also are the released quantities, taking also into account that PVC stabilizers are not the major application of these heavy metals.

   The other part of the experts argue that the control over the cadmium and lead flows could not be guaranteed. Thus in accordance with the precautionary principle cadmium and lead should be banned and removed from the technosphere. As a consequence of this point-of-view, the recycling of all PVC wastes containing cadmium and lead would have to be banned. This concerns major high-volume PVC construction products, thus reducing the utilisable potential for mechanical PVC recycling greatly. However, the ban would be effective for a transition period only, until the major part of the existing stocks of long-life products containing lead and cadmium will have been disposed off. Nevertheless, due to the long-lifetime of the affected products the transition period can be as long as several decades.

   In contrast to heavy metals a possible contamination with **PCB** must be considered as more critical, since the PCB may be released out of the PVC matrix during use. In the past, recycling products with high PCB concentrations have been detected and taken from the market (e.g. nesting boxes for birds, 1994 in Germany) and that the flow of the recycling materials cannot be controlled since they are used in a variety of different products. Thus for those PVC wastes affected (cable insulations and electric/electronic products) further restrictions can be justified (e.g. control of **PCB** contents of input materials). As a consequence, it is likely that the related recycling potentials would be reduced, due to the cost increase associated with the required PCB measurements or other provisions to control the PCB content.

4.2.2 Economic Limits

(1) Apart from the environmental limits, the realisation of the technical recycling potentials is also limited by the overall recycling costs. The recycling costs include:

collection costs (e.g. container, transportation)

\+ costs of sorting and mechanical treatment

= gross recycling costs

\- credits for recyclates

= net recycling costs.

An economic limit of PVC recycling is the **economic profitability**. If profitability cannot be reached the recycling potentials will not be made use of, unless there are legal regulations or voluntary measures promoting or enforcing the recycling. Today, most PVC recycling is carried out under "free market" conditions, i.e. for economic reasons.

(2) Economic profitability of PVC recycling depends on three major factors:

- Apart from the gross recycling costs which depend on the PVC waste or product groups respectively as well as the available recycling and collection technologies
- it is the cost level of the alternative waste management routes (landfilling and incineration especially) which are competing with mechanical recycling on the related markets for wastes, and
- the price level of virgin PVC which determines the achievable selling price for recyclates.

For rough estimates the economic profitability is reached when the **net recycling costs are lower than the prices for alternative waste management routes** for the related PVC wastes.

(3) The available information on the costs of the existing PVC recycling systems (Chapter 3.3) is very limited. However, together with otherwise published cost data they should be sufficient for a rough classification of the economic profitability of the different PVC wastes:

1. High-quality PVC recycling:

a.) In general, the recycling of a major part of PVC **pre-consumer wastes** is profitable. This is why the recycling of pre-consumer wastes constitutes the overwhelming part of PVC recycling today. However, economic profitability is not achieved for all waste groups, like e.g. for some installation wastes (like cut-offs from the laying of pipes or floorings). The profitability depends also on the changing conditions on the markets for virgin PVC and wastes. Today, in many

EU Member States the prices for landfilling are considerably low, due to the upcoming changes in the related legal regulations (technical requirements for landfill sites, phase-out of the disposal of certain waste groups, see 2.2.2). At the same time the prices for virgin PVC are at a minimum level. Both developments have reduced the economic profitability. As a result, ”free market” PVC recycling has been reduced greatly, for example in Italy. However, it can be expected to rise again when market conditions will recover. With these market-related limitations in mind, it can be concluded that the recycling of most pre-consumer PVC wastes is **economic feasible in principle**.

b.) In contrast, the high-quality recycling of **post-consumer wastes** is not profitable, i.e. the net costs are well above the costs for landfilling or incineration at present:

- Net recycling costs for the rigid PVC construction products **pipes, window profiles and ”other profiles”** (cable trays and shutters especially) are in the order of 200 – 300 Euro/ton, not including additional provisions for the separation of the wastes at the construction sites. The prices for landfilling vary greatly in the EU. 150 Euro/ton (including transportation) can be regarded as an upper limit (only a few landfill sites have higher charges). The average level is much lower. Thus recycling cannot compete with landfilling if the net recycling costs are to be covered. However, in the next years the economic conditions for recycling are likely to improve. The phase-out of the direct landfilling of plastics in some Member States and the technical requirements imposed by the EU landfill directive will increase landfill costs or they will make incineration to the major waste disposal route. Incineration costs including transportation reaches 200 Euro/ton in the majority of the existing incineration plants which comply with stringent emissions standards. Therefore, the recycling of pipes, window profiles and ”other profiles” will come nearer to the economic threshold in the next years.
- Net recycling costs for PVC **flooring** are in the order of 300 – 400 Euro/ton. We do not expect that economic profitability can be reached since the cost gap to landfilling or incineration is too large to be closed by the expected future cost changes.
- The same conclusion holds for **PVC bottle** recycling. For the **remaining PVC post-consumer products** which are suitable for high-quality recycling (shoes/soles and sheets), there are no cost data available. However, due to the necessary considerable provisions for collection and sorting we expect that the net recycling costs for these products will also reach an order of magnitude which make competitiveness with landfilling or incineration impossible.

2. Low-quality PVC recycling:

a.) As in the case of high-quality recycling, the low-quality recycling of a major part of PVC **pre-consumer wastes** is **economic feasible in principle**, taking into account the market-related limitations and the restriction that economic feasibility does not apply for 100% of these wastes.

b.) In the recycling of **post-consumer wastes** the situation varies greatly depending on the product groups:

- **Cable insulation** is the only post-consumer waste which is recycled at competitive costs. This is due to the special situation that these materials arise as a waste fraction from cable recycling, free of collection and other costs, and in a ready-to-process quality for their use in the extrusion of new products. There is a similar situation for PVC in the mixed plastics fraction from the recycling of **electric/electronic scrap**. So, with electric/electronic scrap recycling increasing in the next years it can be expected that the recycling of the mixed plastics fraction (including PVC) will be economic feasible as well.
- The costs for the recycling of PVC films in **packaging wastes** are considerably high. Generally the collection of PVC packaging films and other PVC products is included in the different packaging recycling schemes which are existing or are being established in the Member States. For the packaging recycling systems in Austria and Germany the costs for the plastics fraction are between 700 and more than 1.000 Euro/ton. This is far from economic profitability.
- For the **remaining PVC wastes** which are suitable for low-quality recycling (hoses, profiles, office supply, printing films, rigid profiles and sheets arising in commercial wastes) no specific cost information is available. We expect that these PVC wastes will be collected together with other plastics wastes at the company sites, with lower degrees of contamination than in the household collections and thus reducing the sorting requirements. As a consequence the costs will be lower than the household collections (packaging), although still far from reaching economic profitability.

Apart from the cost considerations low-quality PVC recycling can be limited due to **market restrictions**: Up to now, the low-quality recyclates have been applied for a limited number of products, a part of it have been especially designed for the use of the recyclates (e.g. traffic cones, back layers of industrial floorings). So, with expected increasing waste arisings in the future, the market of these ”recycling products” may be too small to absorb the resulting quantities of low-quality recyclates. However, the market for these products is not once-for-all given but it can be enlarged by the design of new products.

4.2.3 Conclusions

(1) As a conclusion of the environmental and economic limits of PVC recycling the different PVC product groups can be arranged in a **portfolio** according to the economic and environmental performance of their recycling (Figure 4-1):

- The most favourable position have those PVC wastes which are recycled at competitive costs (high economic performance) and at the same time providing clear environmental benefits (high environmental performance). This applies for the **high-quality** recycling of a major part of **PVC pre-consumer wastes**.

- On the opposite side there are those PVC wastes where recycling is not competitive due to high costs and environmental benefits are small or not existent. This applies for the **low-quality** recycling of PVC in **mixed plastics** wastes from **packaging** collections and collections in **industrial and commercial enterprises**.

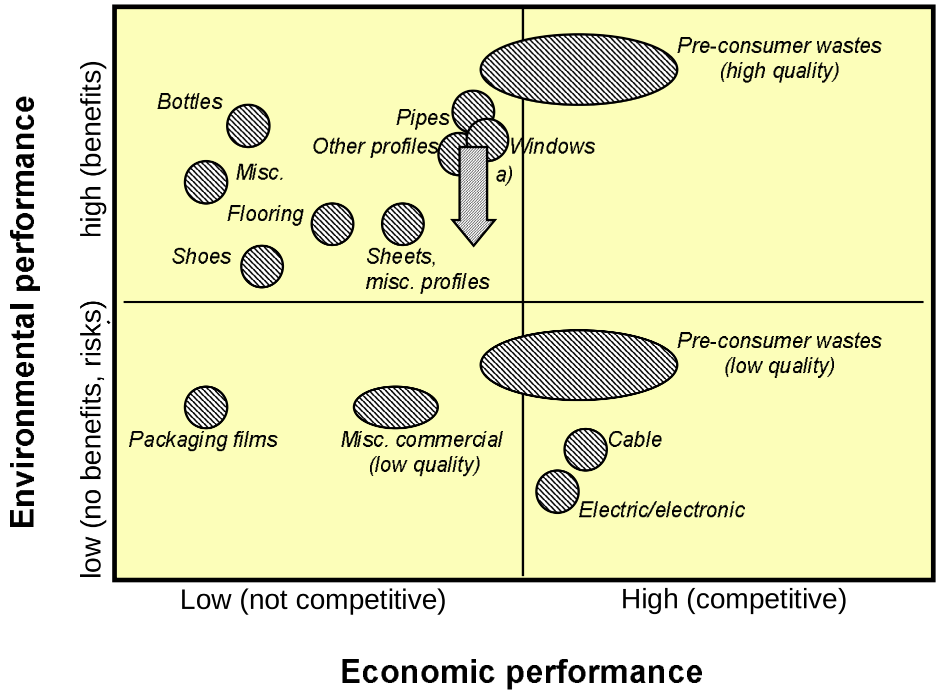
- The recycling of PVC waste from **cable** and **electric/electronic** scraps is competitive economically whilst at the same time the environmental performance is low, due to the limited environmental savings (resources, emissions) and the potential toxicological risks. The **low-quality recycling** of PVC **pre-consumer wastes** must be also classified in this group.

- All PVC **post-consumer wastes** which are **suitable for high-quality recycling** belong to the fourth group – environmental benefits and comparatively high costs. For pipes, windows[16] and ”other profiles” the gap to economic competitiveness is smallest compared to the other PVC products where recycling costs are much higher than incineration or landfilling.

(2) This portfolio will be used as a basis for the definition of future scenarios of PVC recycling in Chapter 5.2 below.

16) The environmental performance of the recycling of window profiles have been evaluated as worse than that of pipes and profiles, due to the cadmium issue (see 4.2.1).

Figure 4-1: Economic and Environmental Limits to PVC Recycling



a) If cadmium and lead stabilisers are evaluated as a significant risk the position of pipes, windows and other profiles must be changed to lower environmental benefits

4.3 Future Prospects and Measures to Improve Mechanical PVC Recycling

RÉSUMÉ OF THE PRESENT SITUATION

(1) Today, PVC recycling is focussed on those areas where economic profitability is achieved, that is pre-consumer wastes and post-consumer cable insulation wastes. The majority of PVC post-consumer wastes is landfilled. Post-consumer recycling systems exist for packaging wastes – enforced by the packaging regulations of the EU and individual Member States – and for some construction wastes in a limited number of countries – all of them have been established voluntarily by the related PVC industry.

For the evaluation of the present situation two aspects must be taken into account:

– PVC post-consumer waste arising is still comparatively low, due to the **time lag** to PVC consumption (which started to increase to the present level in the 1960s and early 1970s). Today, total PVC waste arising is not more than 40% of PVC consumption. For the major product groups with high potentials for mechanical recycling the ratio is even smaller: 2% for pipes, 5% for windows and 20% for other building profiles. For some of the important products a significant increase of the waste arising is not expected before 2010.

– Not only the absolute recycling quantities are low but also the **recycling rates**: The recycled PVC post-consumer waste quantities are **far from reaching their potentials** outlined in Chapter 4.1 and 4.2: Today, only 3% of PVC post-consumer wastes are re-cycled (whilst for pre-consumer wastes recycling rates of more than 80% are achieved).

(2) Taking into account that there are no recycling regulations for the management of the major part of PVC-related wastes the main reason for the low recycling rates is that PVC recycling is **too far from reaching economic competitiveness** (see 4.2). This means that the (net) cost of the whole ”recycling chain”, including the cost of the waste owners (e.g. for separation of PVC at construction sites or transport to collection points) and the costs for the operation of the recycling organisation (collection, sorting, treatment and marketing of the recyclates), is significantly higher than the cost of landfilling which is the major option for PVC waste disposal at present.

– The cost disadvantage is mainly due to low PVC contents in the related waste streams, composite PVC applications, or PVC in mixed or contaminated waste collections which require **expensive collection (and sorting) operations** to separate PVC fractions of a suitable quality – or, in the case of low quality recycling, the achievable prices for the recycling materials are low.

– Another short-term reason which is specific to the present situation is the ”double squeeze” of the profitability of plastics recycling by very **low prices for virgin plastics** on the one side and very **low prices for landfilling** on the other side, at least in countries like Germany where price dumping is practiced as a consequence of the coming ban of the landfilling of reactive wastes including plastics.

Consequently, unless there are no legal or administrative measures (e.g. the existing packaging regulations), voluntary agreements or public contracts (like e.g. in the Netherlands or Denmark) the incentives for the recycling of PVC post-consumer wastes are low.

(3) An important factor which determines the prospects of the **existing voluntary recycling systems** which have been established by the PVC industry to improve the

environmental performance and/or the public image of PVC, is the type of financing. The prospects for "subsidized systems" where the waste owner is charged with a fraction of the actual costs only (like e.g. in existing plastics pipe recycling systems) are better than for "non-subsidized" systems where the recycling fees cover total costs. With "subsidized systems" we define recycling systems which are financed by voluntary contributions (in case of voluntary recycling systems established by industry) or non-voluntary fees (in case of legal obligations like the packaging regulations). Due to the comparatively high cost level of recycling the "non-subsidized" fees (together with additional costs at the waste owners) would be much higher than the prices for alternative waste management routes (landfilling especially). The "subsidisation" compensates the higher prices and the related economic disincentives for the waste holders to collect wastes for recycling.

(4) There are additional factors which are responsible for the low level of PVC post-consumer recycling. **Technical standards** especially, which have excluded the use of plastics recyclates in important product groups like pipes by now, must be mentioned here.

However, the adaptation of many of the related standards is in progress. In some countries, like the Netherlands (for pipes) or Italy, industrial standards which permit the use of recyclates have been developed already. These changes will make an improved utilisation of the existing PVC recycling potentials possible.

FUTURE CHANGES DUE TO LEGAL AND VOLUNTARY MEASURES IN FORCE OR IN PREPARATION

(5) Also as a consequence of the legal regulations and voluntary measures in force or in preparation an **improvement of the conditions for PVC recycling** can be expected for the future.

The following legal regulations must be mentioned here (see also Chapter 2.2.2):

- The EU and national **landfilling** regulations impose technical and economic requirements for landfill sites which will involve an increase in costs or landfill fees respectively. In addition to this, some Member States like the UK, Denmark, Sweden and Finland have introduced landfill taxes, which aim at encouraging recovery and recycling to reduce landfilling. In some countries like Austria, the Netherlands or Germany landfilling of PVC and other plastics will be phased-out in the next years according to the national regulations. As a conclusion the competitive pressure to PVC recycling imposed by landfilling will be reduced.

- As a consequence of the landfill regulations **incineration** will be the sole route for the final disposal of PVC wastes in some Member States, apart from recovery (mechanical recycling, feedstock recycling, energy recovery). On an average, incineration costs are higher than landfill costs, taking also into account that the operation of low-cost incineration plants which do not comply with state-of-the-art emission control technology is likely to be phased out, also as a result of the EU draft directive on waste incineration. This is an additional factor improving the conditions for PVC recovery and recycling.

- For important waste streams (also including PVC) **"recycling regulations"** have been adopted or are in preparation, fixing targets for recycled quantities or separate collection. They include the European and national packaging regulations and the draft directives on electric/electronic equipment and end-of-life vehicles. There is no European regulation for **construction and demolition wastes** which is the most important waste stream for PVC. Only in a few Member States related measures exist. For example, in the Netherlands, Sweden and Denmark there are national programmes to increase recycling and recovery of these wastes, in Austria an ordinance requires the separation of plastics and other fractions at the construction sites and in Germany there exist similar regulations on a regional level, being accompanied by local/regional landfill surcharges for commingled construction and demolition wastes.

(6) In addition, the related **voluntary agreements and contracts** between Government and industry in some Member States will encourage PVC recycling. They include e.g. the existing commitments of industry to reduce PVC flows into incineration in Denmark, to establish recycling systems for window profiles and pipes in the Netherlands or the currently negotiated commitment to reduce PVC flows going to landfills in the UK. These agreements are the major basis for the existing recycling systems for PVC post-consumer wastes. However, many systems are not yet fully developed and they are limited to few Member States by now.

FURTHER MEASURES TO IMPROVE PVC RECYCLING

(7) Altogether, there exists already a lot of waste management measures in the EU whose implementation will improve the conditions for PVC recycling (including mechanical recycling, but feedstock recycling and energy recovery as well).

As a consequence, **measures to increase PVC recycling** beyond this trend development must focus on:

- increasing the utilisation of the existing recycling systems and the further development of these systems,
- broadening the regional scope of the existing recycling systems aiming at an EU-wide coverage,
- establishing supplementary recycling systems for those PVC products/wastes which are suitable for mechanical recycling but have not yet included in the existing recycling activities; PVC profiles in construction wastes and some PVC products in household

and commercial wastes (especially footwear, printing films and sheets) are concerned here.

With regard to the different PVC product groups the major focus of additional measures must be on **PVC in construction and demolition wastes** where the mechanical recycling potentials are high (both quantitatively and qualitatively) and the recycling activities are not reaching far enough with regard to both regional spread and PVC product groups covered (see above).

With regard to the different steps in the recycling process the major focus of the additional measures must be on the **collection** of the wastes. The collection is the major bottleneck for mechanical PVC recycling in terms of costs and achievable recycling rates. To achieve sufficiently high collection rates

– the collection systems must include a sufficient number of collection points to make a broad regional accessibility possible and
– the recycling costs to be paid by the waste owners must be lower than the fees for waste disposal (landfilling and incineration) – otherwise there are no incentives for recycling.

(8) Potential political instruments to encourage separate collection of PVC range from

- statutory orders or prohibitions,
- over ”economic” instruments
- to voluntary agreements.

Possible **statutory regulations** include an EU-wide requirement to **separate mineral and non-mineral fractions** (including PVC and other plastics) of construction and demolition wastes on the construction sites or EU-wide **recycling quota** for the relevant waste streams, i.e. construction and demolition waste, specific municipal solid waste fractions like footwear/textiles and commercial/industrial plastics wastes (including PVC printing films or sheets). Another potential statutory measure is the modification of the European landfill directive by inclusion of a definitive **ban on the landfilling of plastics** and other reactive components, following similar national regulations and being also valid for construction and demolition wastes.

Possible **”economic measures”** are **taxes or levies on landfilling or incineration** setting financial incentives for recycling, while at the same time the income from the taxes can be used to subsidize recycling systems to make the separate collection at competitive costs possible. A specific measure in this context is the **”internalisation” of the PVC-specific external costs in waste incinerators** (for flue gas treatment), e.g. by an allowance for the operators of incinerators paid by the PVC industry and re-financed over the PVC price. Another possibility is to enforce recycling organisations for construction and demolition wastes similar to those existing for packaging wastes, by **imposing overall recycling goals** and leaving implementation and financing up to industry. There are also ”soft” measures for supporting the acceptance of the existing and possible future recycling systems, like **information campaigns**.

Finally the related PVC industry can be committed to increase PVC recycling or the recycling of the relevant waste streams respectively by **voluntary agreements**, following the examples of some Member States. Such agreements may be made on the EU level or separately for the individual Member States.

(9) Apart from the objective to increase the recycled quantities the environmental benefits and risks must be taken into account for a general improvement of PVC recycling.

First of all, most of the potential measures to increase PVC recycling do not encourage specifically mechanical recycling but PVC recovery and recycling in general. High-quality mechanical recycling is the environmentally most favourable recovery option as a rule, however in most cases the costs are higher than for feedstock recycling or energy recovery. Thus, for environmental reasons, **flanking measures to ”protect” high-quality mechanical recycling against feedstock recycling or energy recovery** may be necessary. In contrast, **low-quality mechanical recycling should not be encouraged** by specific measures unless significant environmental advantages over feedstock recycling or energy recovery can be proven.

Further measures may be necessary to **reduce environmental risks** associated with mechanical PVC recycling. They have been discussed in Chapter 4.2.1 above. Depending on the position on the assessment of these risks

– a ban on heavy metal stabilizers (cadmium and lead) in PVC recyclates may be justified (as a consequence, the recycling of end-of-life window profiles would have to be stopped then, for some of them were stabilised with cadmium, and products like pipes and building profiles which are stabilised with lead are affected too) and
– a phase-out of the mechanical recycling of PVC wastes from cable and electronic scrap recycling which may contain PCB may be reasonable for precautionary reasons.

5. Scenarios of the Future Development of Mechanical PVC Recycling

5.1 Future Development of PVC Waste Arising in the European Union

(1) The future development of PVC waste arising by 2020 has been estimated by **EuPC**. In this estimation PVC waste arisings have been calculated as the result of the consumption of the different PVC products, for which detailed time series going back to the 1950ies have been used, and the estimated average lifetime of these products. The average lifetimes range from 1 year for packaging up to 45 years for pipes. So, for each past and future year a calculation is performed at which point in time the consumption quantity of this year will become waste. For example, the waste arising of pipes in 2010 is the result of the pipe consumption 45 years earlier, i.e. in 1965. In the EuPC-model 59 different products and product groups are distinguished. This classification is based upon the PVC classification scheme developed in this study (see Chapter 2.1).

As a matter of fact, these calculations are affected with different **uncertainties**. The most important ones concern

- the future development of PVC consumption which influences directly the future waste arising of short-life products, and
- the average lifetimes of the long-life products (in the building sector especially): Due to the fact, that the waste arising in 2020 is still in the dynamic part of the waste function, where the increase of waste quantities is comparatively high (see Chapter 3.1), small differences between the estimated average lifetimes and the actual lifetimes of the products result in significant variations of the waste volumes.

(2) Furthermore, the data on the present PVC waste volumes supplied by the Member States for this study differ from the data estimated by EuPC. This is due to the fact that many of the "national data" are based upon a different estimation method, namely on the PVC-content in the different waste streams (municipal solid wastes, building and construction waste, etc.) for which statistical data exists. However, the PVC content is very uncertain, so that these estimations are likewise affected with considerable uncertainties. By comparing the results of all available estimations, the range of uncertainty of the EuPC data is in an order of ±15% for present PVC waste arising. The projection on the future waste volumes is affected with much higher uncertainties.

(3) Due to the time lag between PVC consumption and waste arising the PVC waste arising will increase drastically until 2020 compared to the present level of about 4.1 million

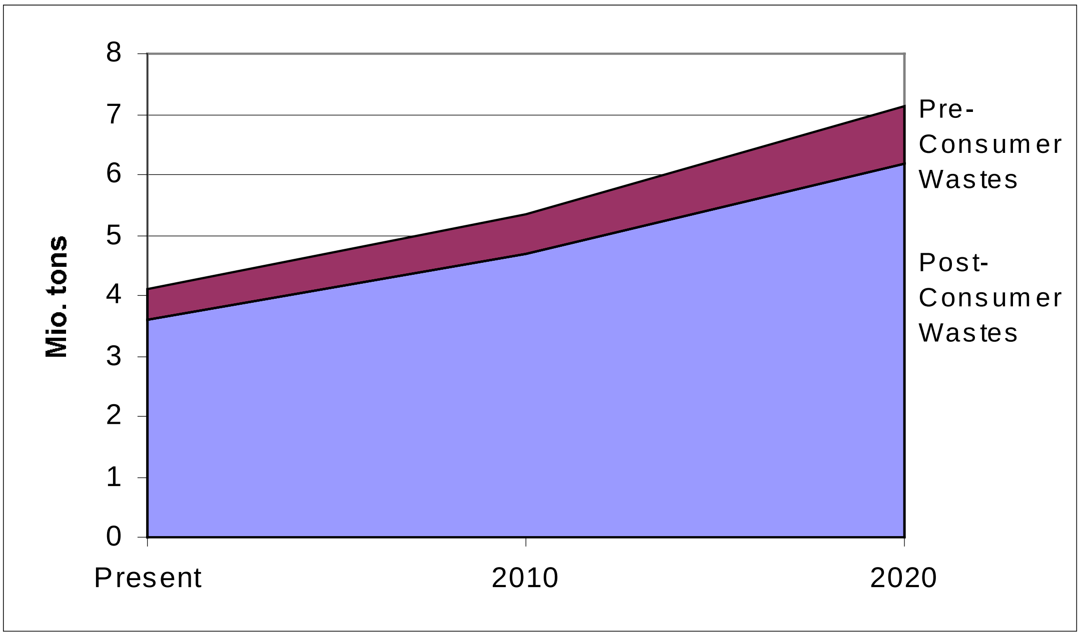
tons per year (compound-basis; cf. chap. 3.1). The results of the EuPC projection for 2010 and 2020 can be summarised as follows (Figure 5-1, all figures refer to PVC compound):

- The **post-consumer wastes** will increase from about 3.6 million tons at present to about 4.7 million tons in 2010 and 6.2 million tons in 2020. This is an increase of 30% till 2010 and even 85% till 2020.

- The **pre-consumer wastes** will increase from about 500 ktons at present to about 650 ktons in 2010 and 920 ktons in 2020. This is an increase of 30% till 2010 and 85% till 2020.

- So **total waste arising** is about 5.4 million tons in 2010 and **7.1 million tons in 2020**. This is equal to an increase of 30% till 2010 and 75% till 2020.

Figure 5-1: Projection for the development of PVC waste arising by 2020 (EuPC)



(4) This estimation is used as a basis for this study. It is based upon a **forecast of PVC consumption** in the EU which has been developed by the **EuPC** using the projections of different experts of the different market segments of the PVC industry (see Table 5.1). EuPC expects that total PVC consumption will increase by 65% until 2020 (about 2.5% per year). A great deal of this increase stems from the PVC consumption of short-life products for household and commercial applications increasing by 150% (4.4% per year). Consequently there will be structural shift in the PVC consumption with an increasing share of short-life products. In the period by 2020 these short-life product will add to the PVC waste volumes quickly. As a consequence, EuPC projects a comparatively stable relation between PVC

waste arising and PVC consumption as well as between post-consumer and pre-consumer PVC wastes, in spite of an over-proportional increase of wastes from long-life products.

Table 5.1: Forecast of PVC Consumption in the EU by 2020 (EuPC)

	PVC Consumption (1'000 tons)		
Product groups	**Present**	**2010**	**2020**
Building Products	4'250	5'791	6'725
Packaging	680	633	788
Furniture	102	178	299
Other household/ commercial	1'346	2'054	3'362
Electric/electronics	545	587	635
Automotive	433	483	550
Others	72	76	84
Total	**7'429**	**9'802**	**12'443**

The EuPC projections for the short-life PVC products seem to be very optimistic. We would rather expect a certain saturation of the PVC consumption with decreasing growth rates in the mid-term and no major shift in the PVC consumption structure. As a consequence,

– total waste arising would increase faster than PVC consumption (as a result of the wastes from long-life products) and approach to the PVC consumption volumes and
– the contribution of pre-consumer wastes in total PVC waste would decrease, whilst the contribution of post-consumer wastes would rise.

Nevertheless, the EuPC forecast can be taken as a reasonable basis for the waste projections in this study – first for practical reasons (the elaboration of a sophisticated forecast like that of EuPC is beyond the scope of this study) and second due to the fact that the consequences regarding the PVC recycling potentials do not differ from our expectations essentially: Whatever the assumptions on the future PVC consumption **PVC wastes with lower recycling potentials will increase over-proportionally,** thus resulting in less favourable overall conditions for mechanical PVC recycling. In the EuPC forecast these are post-consumer wastes (see 4.1), whilst our expectations would result in an over-proportional increase of "difficult-to-recycle" post-consumer wastes compared to "easy-to-recycle" pre-consumer wastes.

(5) The **composition of PVC post-consumer waste arising** by product groups which results from the EuPC projection is shown in Figures 5-2 and 5-3 for 2010 and 2020 respectively:

- The share of building products wastes is increasing from now on, due to the big quantities of long-life PVC products (pipes, cables, window-frames and profiles) which have been put into use in the past, starting in the 1960s and 1970s, reaching the end of their lifetimes. According to the EuPC estimation the share of building products wastes will increase from 28% at present to 36% in 2020 (Figure 5-2).

- Due to the projected high growth rates for the consumption of PVC products for household and commercial applications the contribution of wastes from household and commercial products will also increase, from 28% at present up to 30% in 2020.

- The contribution of packaging will decrease significantly: From about 21% at present it will go down to 13% in 2020.

- Whilst the contribution of automotive wastes will also decrease slightly from 11% to 8%, the shares of the other product groups will remain on a similar level than today.

Figure 5-2: Estimated PVC post-consumer waste arising in 2010 by product groups

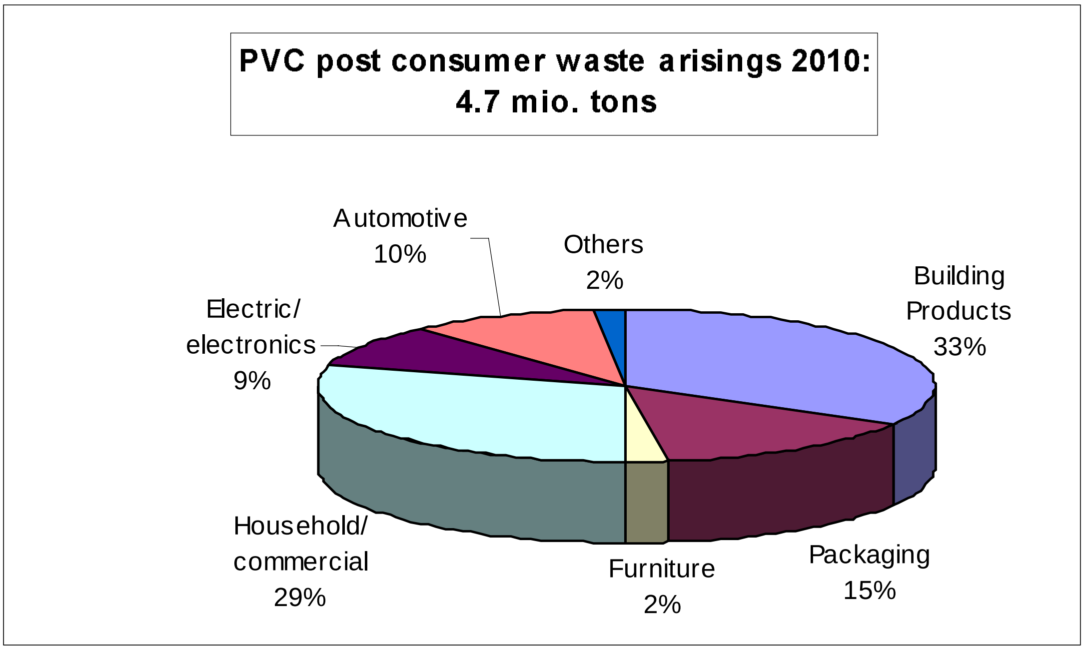
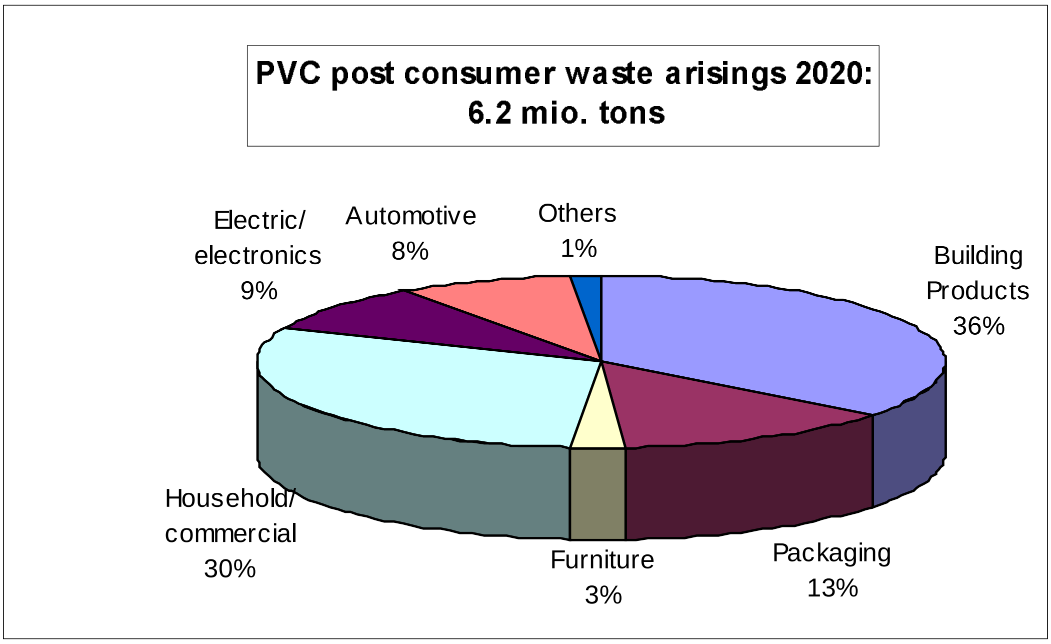


Figure 5-3: Estimated Total PVC post-consumer waste arising in 2020 by product groups



5.2 Future Development of Mechanical PVC Recycling in the EU

RECYCLING POTENTIALS

(1) Based upon the projection of PVC waste arising in Chapter 5.1 the absolute potentials for mechanical PVC recycling can be calculated using the potential recycling rates developed in Chapter 4.2:[17]

- In **2020** the total potential for mechanical PVC recycling in the EU is about **2 million tons** per year (1.4 million tons in 2010), of which 1.2 million tons are post-consumer wastes and 0.8 million tons are pre-consumer wastes.

The recycling potentials represent the maximum recycling quantities which can be achieved theoretically. The recycling quantities which are expected to be achieved in practice are developed below.

17) For each group of PVC wastes (according to Table 4.1 and 4.2 in Chapter 4.2) the waste arising volume has been multiplied by the respective potential recycling rate.

Analysing this potential with regard to its environmental and economic performance (according to Chapter 4.2.3 above) the following conclusions can be drawn (Figure 5-4):

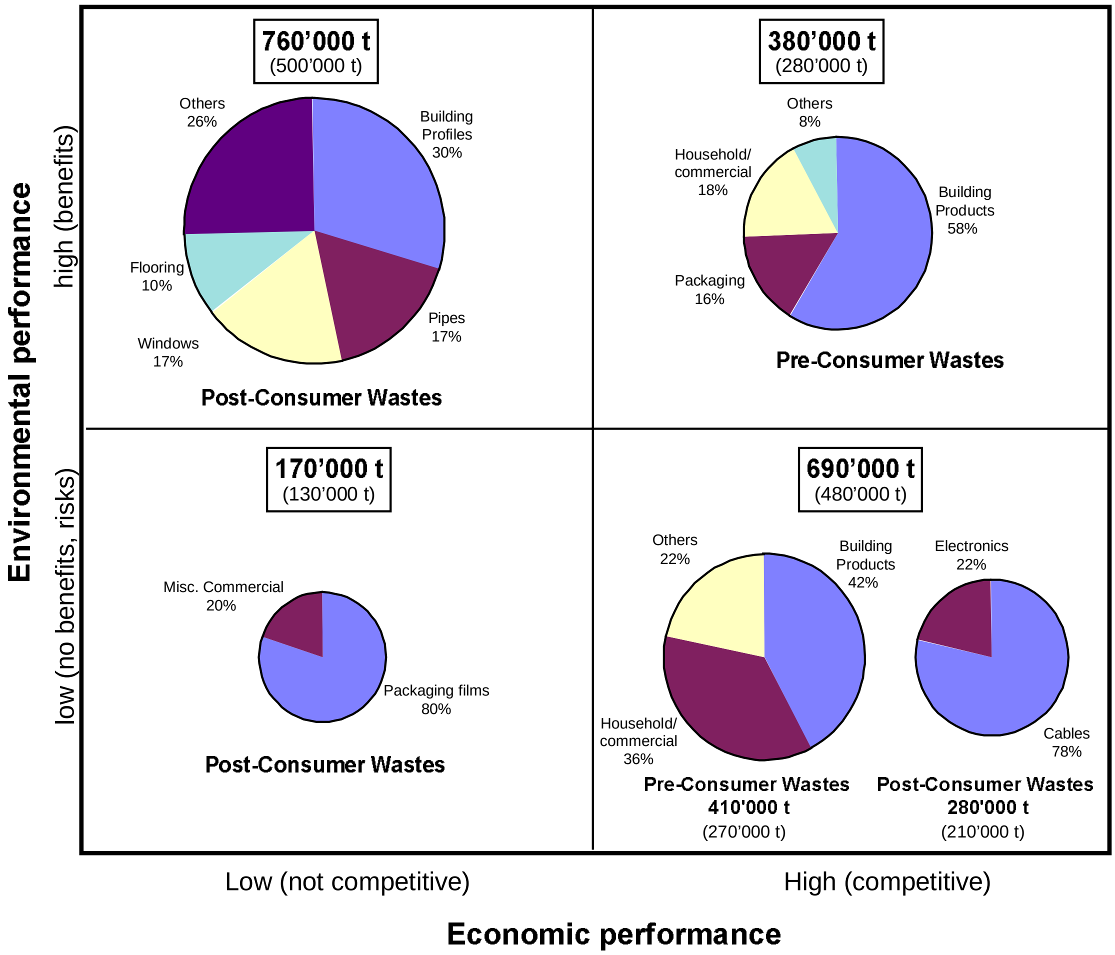
- In 2020, the recycling potential for **PVC post-consumer wastes** is about **1.2 million tons** (compared to 0.8 million tons in 2010). This represents about **19%** of post-consumer waste arisings (see above, 5.1). The major part of this potential (760’000 tons) is for high quality recycling. Less than 25% (280’000 tons) of the potential can be utilised at economic competitive conditions. For the remaining more than 75% recycling is more expensive than waste disposal.

- The recycling potential for **PVC pre-consumer wastes** is about **0.8 million tons**. (compared to 0.55 million tons in 2010). This represents **more than 80%** of pre-consumer waste arisings (see above, 5.1). About one half of it (380'000 tons) is a “high-quality” potential, the other half is a “low-quality” potential (410'000 tons). The complete potential can be utilised at economic competitive conditions.

- Altogether still 54% of the mechanical recycling potential is profitable economically (1.07 million tons) in 2020. 57% of the total recycling potential is a “high-quality” potential, the remaining 43% are for “low-quality” recycling.

As a result of an over-proportional increase in post-consumer wastes relative to pre-consumer wastes, due to the wastes from long-life PVC products which have been produced in the past, there is a **tendency towards a deterioration of the conditions for mechanical PVC recycling** for the decades to come **after 2020**. In the portfolio this is represented by a shift from the ”high quality – low cost” recycling of pre-consumer wastes (upper right quadrant) to higher costs (upper left quadrant) and lower quality (lower right quadrant). By 2020 this tendency is not yet virulent.

Figure 5-4: Potentials for Mechanical PVC Recycling in 2020 (in brackets 2010)



SCENARIOS

(2) The subsequent projections for the future development of mechanical PVC recycling are based upon the assessment of the PVC recycling potential as shown above. In order to describe the scope of influence of measures encouraging or discouraging recycling three scenarios have been defined:

1. **"Trend Scenario":** This scenario describe the development of PVC recycling for the case that no PVC-specific measures will be taken except for those legal, administrative and voluntary measures in force or in preparation. The major assumptions are listed below:

   - **Regulations**: The regulations on **landfilling**, **incineration** and **packaging** of the EU and individual Member States will be implemented consequently or maintained respectively under the current legal conditions, as well as the Directive on **end-of-life vehicles** which is in the second reading in the European Parliament now. Additionally it is assumed that a regulation on **electric and electronic scrap** will be put into effect. As a consequence it can be expected that PVC recycling is encouraged – directly in the packaging and electronic area and indirectly by restrictions and increasing costs for landfilling and incineration. Finally it is assumed that the existing standards concerning cadmium, lead and PCB in the recycling material will not be tightened.

- **Voluntary measures**: It is assumed that the existing voluntary PVC recycling systems established by industry will be maintained and upgraded, under the condition that the costs remain at a level not too far from economic competitiveness. Taken into account the estimated cost levels of PVC recycling (Chapters 4.2 and 3.3) it is assumed that under the major existing recycling systems those for **pipes, window profiles** and **floorings** in Austria, Germany, Italy, Denmark, the Netherlands and UK will be maintained and upgraded[18], whilst those for roofing and bottles will be closed down: Waste arisings of roofing membranes are low, resulting in high logistic costs. Waste arisings for bottles are decreasing, due to the ongoing substitution of PVC bottles by PET bottles.

- **Other assumptions**: It has been assumed that the **prices for virgin PVC** will recover, so that the average real prices by 2020 will be at least on the level of the present ten-year-average. It is also assumed that the technical standards which have by now restricted the use of recyclates in pipes will be changed in accordance with the present drafts, so that the high-quality recycling of pipes will be possible in all EU Member States in due course.

2. **"Ecological Risk Minimisation Scenario":** In this scenario it is assumed that additional measures will be enforced which are led by strict environmental objectives: Mechanical recycling of those PVC wastes will be encouraged which provide clear environmental benefits. A ban of heavy metal additives (lead and cadmium) in PVC and PVC recyclates as well as stringent standards for PCB in recyclates will be enforced, following a risk minimisation approach to these issues. As a consequence

   - the **recycling of all PVC post-consumer wastes containing lead and cadmium stabilisers will be phased out**. The major high-volume products concerned are pipes, building profiles, window profiles and cables. The phase-out will be effective until the major part of the related products will have completed their lifetime (being replaced by heavy-metal free products), thus ensuring sufficiently low heavy metals contaminations. Due to the long lifetimes of the related products it is assumed that it will take longer than 2020 to reach this situation.

   - In addition, **stringent standards for PCB** in recyclates will affect the recycling of **post-consumer cable and electronic wastes** (low-quality recycling). It is assumed that there will be a phase-out of the recycling of these wastes as well, also being effective until after 2020.

18) It is assumed that the recycling systems will be upgraded just to keep pace with the increase in waste arisings, making it possible that current recycling rates of the related PVC products/wastes can be maintained by 2020. For this purpose, inter aliam the number of collection points and the capacity of the recycling plants must be increased in line with the growth of waste arisings.

- The recycling of **pre-consumer wastes** will be not affected.

Table 5.2: Major Assumptions on the Recycling Rates in the Recycling Scenarios

	Scenarios		
	"Trend"	**"Ecological Risk Minimisation"**	**"Selective Improvements"**
High-quality recycling			
Pre-consumer wastes	Potential recycling rates	Potential recycling rates	Potential recycling rates
Post-consumer wastes	Percentage of potential recycling rates:[a)] • pipes: 40% • windows: 70% • flooring: 50% • others: 0%	Potential recycling rates except for: • windows: 0% • pipes: 0% • building profiles: 0%	Potential recycling rates
Low-quality recycling			
Pre-consumer wastes	Potential recycling rates	Potential recycling rates	Potential recycling rates
Post-consumer wastes	Percentage of potential recycling rates:[b)] • cables: 80%[b)] • electronic: 80%[b)] • packaging: 100% • others: 0%	No mechanical recycling except for: • packaging	Percentage of potential recycling rates:[b)] • cables: 80%[b)] • electronic: 80%[b)] • packaging: 100% • others: 0%

a) Estimation based upon the share of the Member States where recycling systems are maintained at total waste arising in the EU

b) Estimation based upon the present recycling rates for PVC from cable scraps and an increase of 30% due to increasing landfill costs making recycling more attractive

3. **"Selective-Improvements Scenario":** In this scenario it is assumed that additional measures will be enforced selectively to encourage PVC recycling in areas with clear environmental benefits but high recycling costs which prevent recycling systems from being implemented. As a consequence

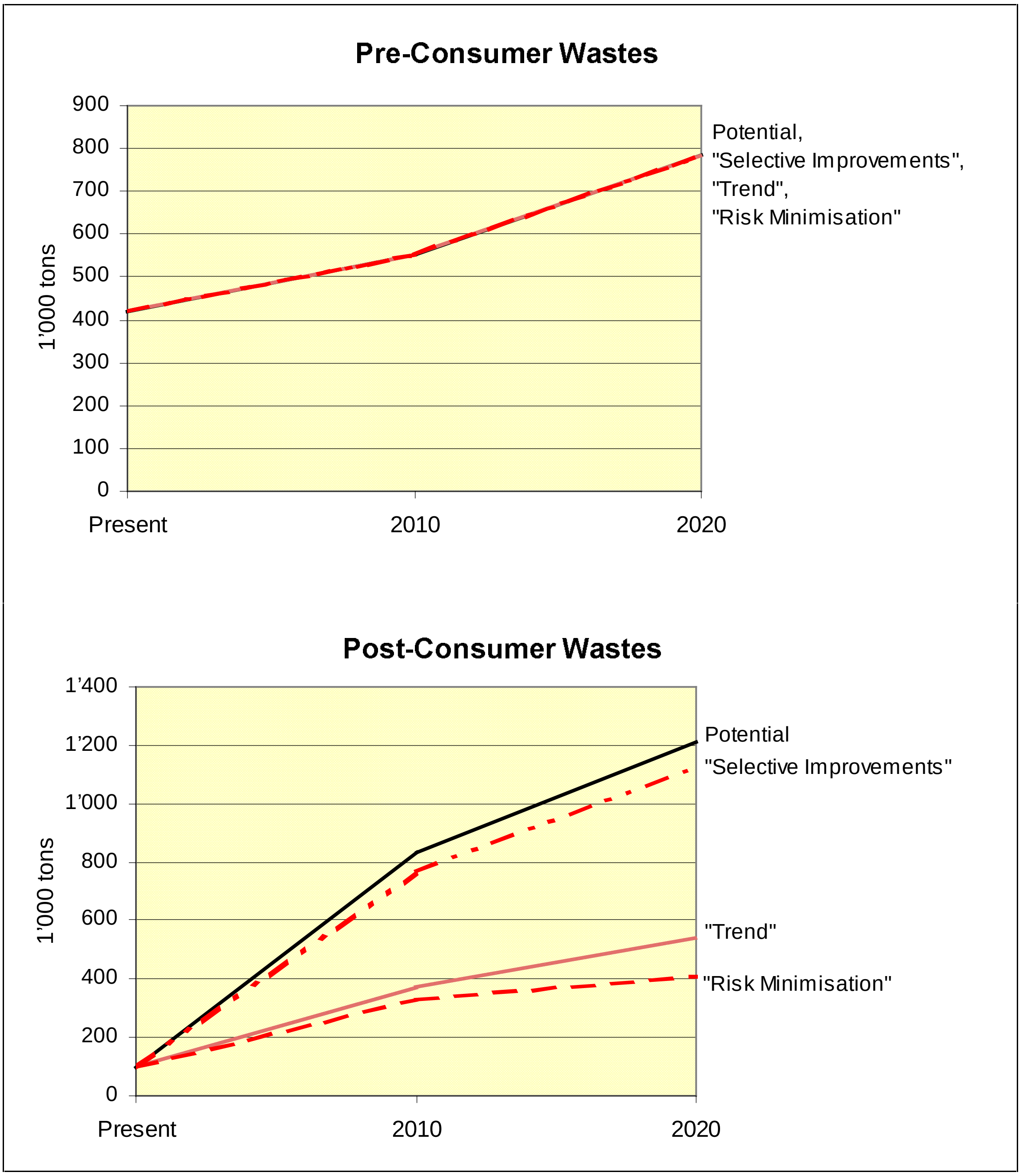
   - the recycling of all PVC wastes which are suitable for **high-quality recycling** is **encouraged** (potential: 760’000 tons + 380’000 tons, see Figure 5-4).[19]
   - For the whole area of **low-quality recycling** no measures are taken, i.e. the trend development which is amongst others determined by the legal regulations

19) Concerning the heavy metal and PCB issue it has been assumed that the present legal regulations will not be modified, i.e. there will be no additional restrictions for the recycling of the related products.

in force or in preparation will be not influenced. This means that the potential for low-quality recycling is used except for ”miscellaneous commercial wastes” (about 35’000 tons) where no regulation exists and where the recycling is expensive with small environmental benefits.

(2) The detailed assumptions in the scenarios concerning the recycling rates are listed in Table 5.2.

Figure 5-5: Development of PVC recycling by 2020 for the different scenarios



RESULTS

(3) At present 520 ktons PVC (compound) are recycled, of which about 100 ktons are post-consumer wastes and 420 ktons are pre-consumer wastes. The recycled quantities are projected to increase by 2020 in all scenarios (Figure 5-5):

- The recycling of **pre-consumer** PVC wastes will increase to 550 ktons in 2010 and 780 ktons in 2020. This increase is the result of the increasing PVC production as forecasted by EuPC (whilst the recycling rates remain at a comparatively stable level, see below).

- The recycling of **post-consumer** PVC wastes differs depending on the scenario:
  - In the **"Trend Scenario"** PVC recycling will increase by the factor 5.4 to reach **540 ktons in 2020**.
  - Due to the restrictions on the recycling of major PVC waste groups the results for the **"Ecological Risk Minimisation Scenario"** are significantly below the "Trend Scenario", reaching **410 ktons** only **in 2020**.
  - The highest increase of recycled PVC quantities is achieved in the **"Selective-Improvements Scenario"** where **1.1 million tons** are reached in 2020. This is not surprising due to the additional measures to increase high-quality recycling while leaving the development of economic competitive low-quality recycling untouched.

At present about 80% of the recycled PVC waste is pre-consumer waste (see 3.1). By 2020 recycled post-consumer quantities increase faster than pre-consumer wastes, due to the long-life products reaching the end of their lifetimes with a time lag and increasing recycling rates due to the additional recycling systems (depending on the scenario).

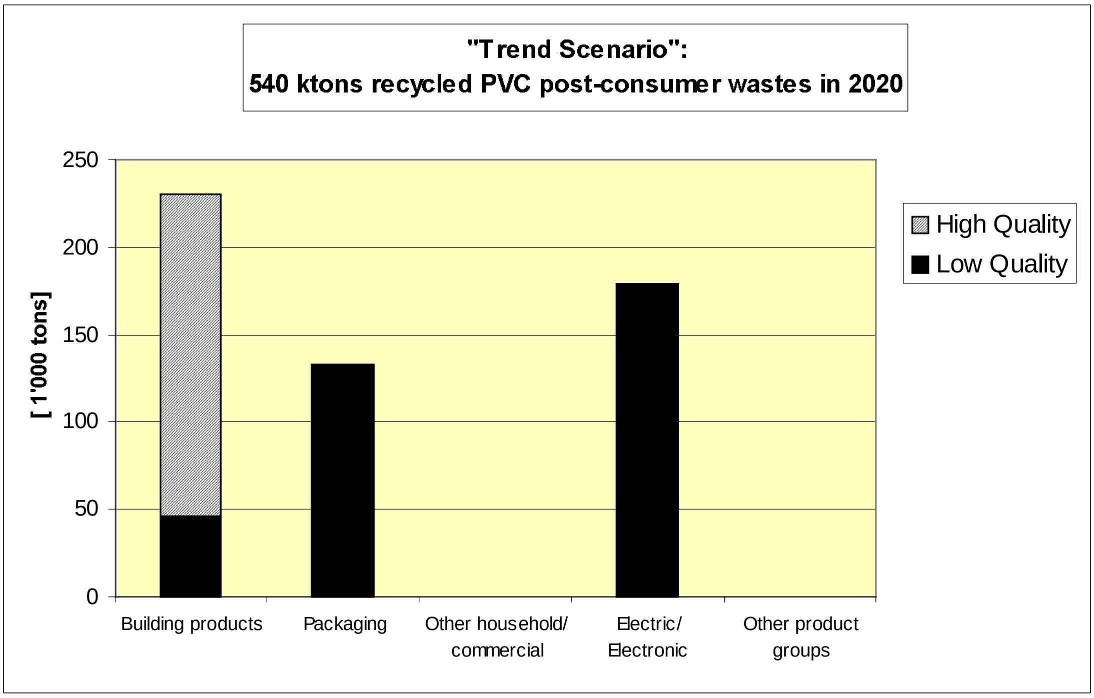
(4) About one half of the recycled **pre-consumer wastes** is processed to “high-quality” recyclates, the other half to “low-quality” recyclates. There are no major shift in this structure by 2020.

Production and installation wastes from building products constitute more than 50% of the recycled pre-consumer wastes at present. By 2020 their contribution will be reduced to about 40%. The major part of the wastes stems from production and installation of floorings and pipes here. The contribution of miscellaneous household and commercial products will increase from 15% to about 35% in 2020, due to the projected over-proportional increase in the production of these products. In contrast, the contribution of wastes from the automotive sector will decrease from more than 15% to less than 10% in the same time. Pre-production wastes from the other product groups are of limited importance.

(5) The **composition of recycled PVC post-consumer wastes** for 2020 is shown in Figures 5-6 to 5-8 for the three scenarios.

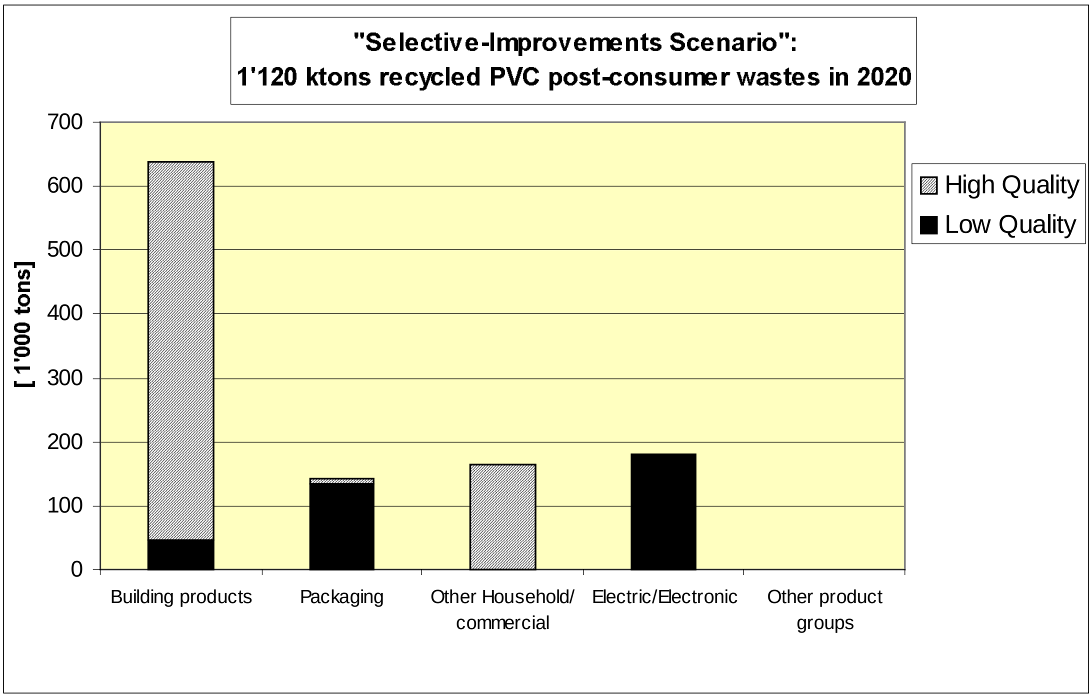
- In the **"Trend Scenario"** (Figure 5-6) building product wastes are the major group to be recycled. In 2020 about one third (180 kt) of total recycled quantities are pipes, windows and floorings which are collected and processed to “high-quality” recyclates by the up-scaled existing voluntary recycling systems. The remaining two thirds (360 kt) of PVC post-consumer wastes are recycled in “low-quality” processes. The plastics fractions from the recycling of cables and other electric/electronic wastes which can be recycled economically, as well as packaging wastes which are recycled due to the legal requirements (Packaging Directive and national regulations) are concerned here.

Figure 5-6: Recycling of PVC wastes by product groups in 2020 (Trend Scenario)



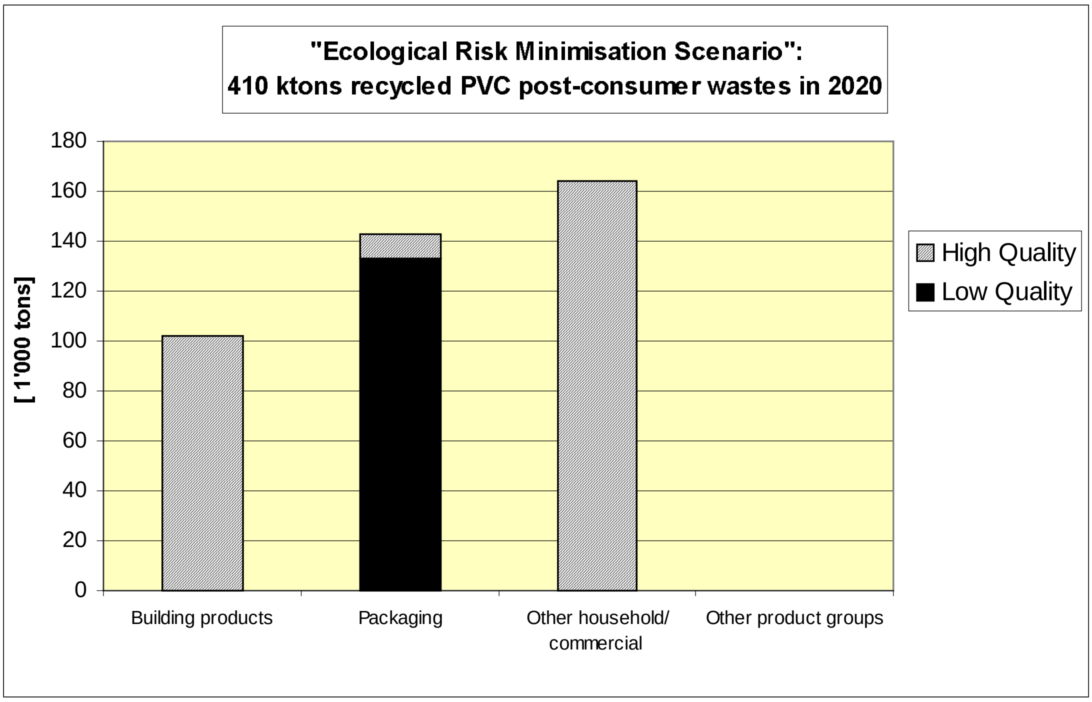
- In the **"Selective Improvements Scenario"** (Figure 5-7) the encouragement and up-scaling of high-quality recycling systems will result in a considerable increase of the recycled building product wastes from 180 kt in the “Trend Scenario” to 590 kt by 2020. This increase concerns pipes, windows and floorings (due to the assumed EU-wide extension of the recycling systems), as well as building profiles (due to the establishment of new recycling systems). In addition to building products it has been assumed that high-quality recycling systems for some household and commercial PVC wastes (sheets, printing films, footwear etc.) will be established resulting in a quantity of 160 kt in 2020. The “low-quality recycling” of PVC wastes from the recycling of cables and electric/electronics and packaging will not change compared to the “Trend Scenario”. In the “Selective Improvements Scenario” altogether 760 kt of PVC wastes are recycled to “high-quality” materials (68% of total recycled quantities) and 360 kt (32%) are recycled to “low-quality” materials.

Figure 5-7: Recycling of PVC wastes by product groups in 2020 („Selective-Improvements Scenario“)



- In the **"Ecological Risk Minimisation Scenario"** (Figure 5-8) the recycling of packaging is maintained like in the “Trend Scenario”. The high-quality recycling for some household and commercial PVC wastes will be established like in the “Selective Improvements Scenario”. Due to the heavy metal and PCB issue the recycling of building products will be restricted to floorings by 2020, resulting in a reduction of the recycled building products wastes from 180 kt in the “Trend Scenario” to about 100 kt. The recycling of electric/electronic wastes will be phased-out completely. Altogether, the mechanical recycling of PVC post-consumer wastes will be 25% lower than in the “Trend Scenario”. In 2020 about two thirds of total quantities (280 kt) will be “high quality” recycling and one third (130 kt) will be “low-quality” recycling.

Figure 5-8: Recycling of PVC wastes by product groups in 2020 („Ecological Risk Minimisation Scenario“)



(6) Although the expected increase in PVC recycling is remarkable compared to the present situation the significance of mechanical recycling for the waste management of PVC must be evaluated against the development of total PVC waste arising. Figure 5-9 shows the **recycling rates**, i.e. the ratios of mechanically recycled PVC quantities to total PVC waste arising, in the three scenarios. The following conclusions can be drawn:

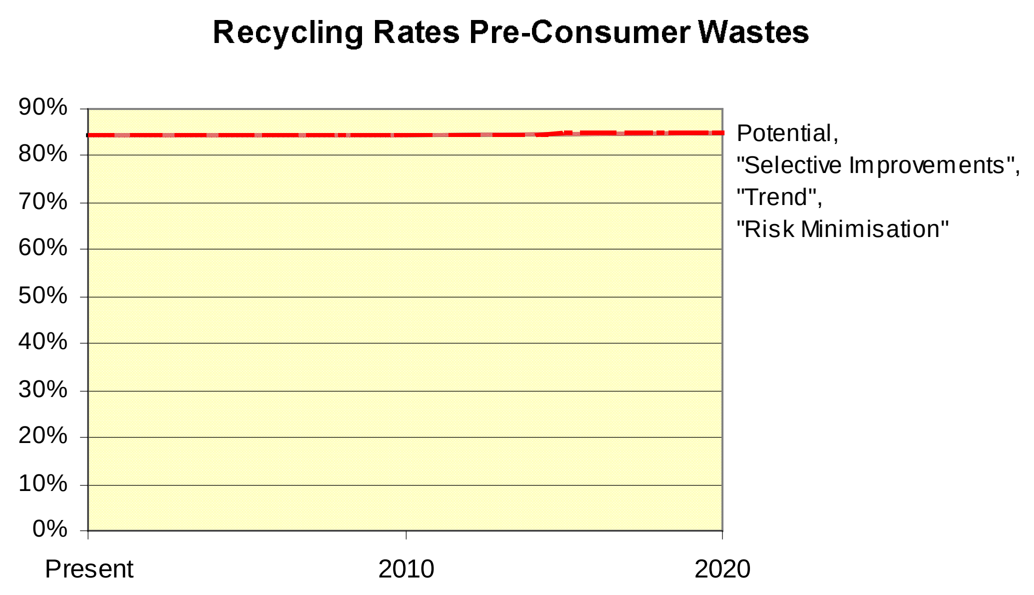
– The mechanical recycling of PVC **pre-consumer wastes** is already straightforward. **Mechanical recycling will remain the major waste management option** here.

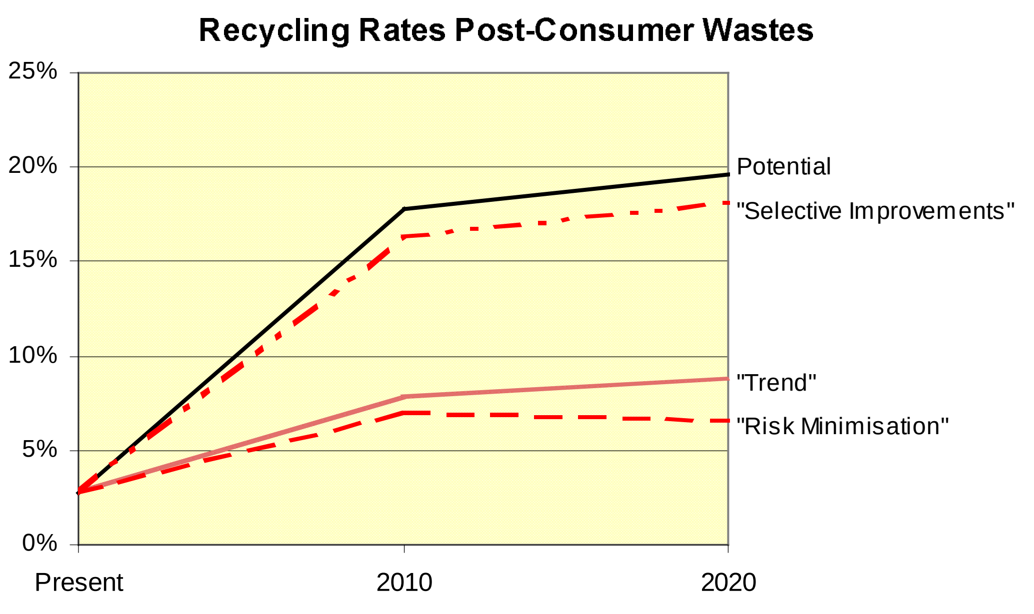
– For the PVC **post-consumer wastes** which will increase faster than pre-consumer wastes the situation is reversed: Whatever the measures taken to improve recycling –, **the importance of mechanical PVC recycling for the management of the PVC post-consumer wastes will remain limited.** Depending on the scenario recycling rates **between 7% and 18%** can be achieved by 2020. This means that the major part of PVC post-consumer wastes must be recovered or disposed of in other ways, i.e. by feedstock recycling, incineration or landfilling.

(7) An additional restriction for the mechanical recycling of PVC post-consumer wastes in the future may be due to the **restricted potentials of new products to absorb recyclates** (a 100% substitution of virgin PVC by recyclates is not possible). If the amount of the collected post-consumer waste for high quality recycling is higher than the usability of the

recyclate for the same product, this leads to bottlenecks. However, for the period till 2020 and beyond, the total absorption potential for high quality recyclates from post-consumer wastes will remain much higher than the production of recyclates. Bottlenecks are expected for single products only, especially for bottles (packaging) and printing films (household and trade). However the recyclates can be used in the production of other PVC products, pipes especially.

Figure 5-9: Pre-consumer recycling rates for the different scenarios





6. Summary and Conclusions

PRESENT SITUATION

(1) The estimated total PVC waste arising in the EU is about **4.1 million tons per year** (PVC compounds).

This compares to a current PVC consumption of 7.4 million tons per year. Nearly 60% of the PVC consumption is used for long-life applications in the construction sector (flooring, pipes, profiles), with estimated lifetimes of up to 50 years. About 25 – 30% are short-life applications (packaging, various household and commercial products). The remaining 10 – 15% are used for products with medium lifetimes such as components for cars, furniture or electronic equipment. PVC consumption started in the 1950ies and reached significant levels not before the end of the 1960ies. Thus, the major part of the long-life products produced in the past are still in use and do not contribute to wastes yet. This explains the considerably lower level of PVC waste arising compared to PVC consumption.

However, with more and more of the „old products“ reaching the end of their lifetimes in the coming years PVC waste arising will increase significantly. The environmentally sound and cost-effective management of these wastes is the task to be performed in the next years.

(2) **Mechanical recycling** is one option to deal with the PVC wastes. In principle mechanical recycling of a major part of PVC wastes is technically possible, although the quality of the recycling materials is not 100% equivalent to virgin PVC in most cases. So, recyclates from PVC post-consumer wastes especially are used in new products as separate recyclates layers together with virgin PVC layers (e.g. pipes or floorings).

However, the major part of PVC post-consumer wastes is **landfilled** today. The existing recycling activities are concentrated on limited areas:

- In terms of recycled quantities the recycling of **pre-consumer wastes** (production wastes and installation wastes, e.g. cut-offs from the laying of floorings or pipes) is dominant today. The recycling is economically profitable and is thus carried out under „free market conditions“. All over the EU a large number of small and medium plastics recyclers are involved.
- The recycling of **post-consumer wastes** is limited so far: The recycling of PVC **cable insulation** wastes from cable shredders is profitable, since they can be easily collected and used as low-grade material for a limited spectrum of products (e.g. traffic cones, industrial floorings).
  The recycling of PVC **packaging wastes** has been established in the frame of the related packaging regulations (EU and national). The recycling of PVC bottles must be

mentioned here (existing in France, Italy, the U.K., Spain and Portugal), but a major part of PVC packaging goes into mixed plastics recycling routes where the potential of mechanical recycling is limited.
In some Member States, including Austria, the Netherlands, Germany, Denmark and Sweden, recycling systems for **some PVC building products** (pipes, window profiles, floorings, roofing membranes) have been established. All of them are based upon **voluntary initiatives** or related agreements between Government and industry. These systems are not competitive economically. A part of them are financed by industry, in other systems the waste owners have to pay a fee which covers the recycling costs partially or completely.

(3) The present PVC waste arising of 4.1 million tons is composed of about 3.6 million tons of post-consumer wastes and 500’000 tons of pre-consumer wastes. Altogether, about **520'000 tons** of PVC are recycled today:

- Recycling of PVC **pre-consumer wastes** is comparatively straightforward. At present more than 80% (about **420'000 tons**) are recycled.

- Recycling of PVC **post-consumer wastes** is limited: The total quantity is about **100'000 tons** in the EU, thus representing a recycling rate of less than 3%.

Even further, it must be taken into account that the major part of the recycled post-consumer wastes (about 60%) are cable insulation and packaging wastes in mixed plastics fractions which are „downcycled“ to low-grade materials (**„low-quality recycling“**). Only the voluntary recycling systems for pipes, floorings, windows, roofing, bottles and some specific products are qualified for the production of PVC recyclates which can be re-used in the same applications **(„high-quality recycling“**).

The major reason for the low recycling rates is that PVC recycling is **too far from reaching economic competitiveness**. The low PVC contents in the relevant waste streams, composite PVC applications, or PVC in mixed or contaminated waste collections require expensive collection (and sorting) operations to separate PVC fractions of a suitable quality – or, in the case of low quality recycling, the achievable prices for the recycling materials are low. Another short-term reason which is specific to the present situation is the „double squeeze“ of the profitability of plastics recycling by **low prices for virgin plastics** on the one side and **low prices for landfilling** on the other side, having given rise to a considerable reduction of PVC recycling in countries like Italy.

Except for packaging wastes there are also **no legal regulations** which are qualified to enforce PVC recycling of the major part of PVC-related wastes.

Additional limiting factors for PVC recycling are **technical standards** which have excluded the use of plastics recyclates in important product groups like pipes by now.

(4) It should be mentioned that some of the potentials and limits to PVC recycling are also true for the recycling of **other plastics**, whilst other potentials and limits are specific to PVC, e.g. the presence of chlorine limiting the potentials for mixed plastics recycling or the higher proportion of building products where the collection is comparatively easy. However, it is **not the objective of this study to compare the recycling of PVC with the recycling of other plastics**. This would need further investigations.

FUTURE TRENDS

(5) By **2020 PVC waste arising** is projected to reach about **7.2 million tons per year** in the EU, that is 80% more than today. PVC post-consumer wastes will increase to 6.2 million tons and PVC pre-consumer wastes will increase to 0.9 million tons. Increasing the recycling rate would mean that PVC recycling must grow at an even higher rate.

For the coming decades we expect an improvement of the general conditions for PVC recycling, due to the legal regulations and other measures in force or in preparation:

- The adaptation of the technical standards limiting the use of plastics recyclates is in progress.
- As a result of the EU and national **landfilling** regulations requiring technical and economic provisions for landfill sites or even phasing-out the disposal of plastics wastes, of **landfill taxes** in some Member States and of the EU **directive on waste incineration** regulations requiring the installation of state-of-the-art emission control technology in waste incinerators, the costs for the disposal of PVC wastes will increase. As a conclusion the economic competitiveness of PVC recycling will improve.
- The adoption of the draft directives on **electric/electronic equipment** and **end-of-life vehicles** together with the ongoing implementation of the packaging directive in the Member States will enforce recovery and recycling systems for the related waste streams where also the PVC content in these products is included.
- In addition, the different **voluntary agreements and contracts** between Government and industry in some Member States will encourage PVC recycling. They include e.g. the existing commitments of industry to reduce PVC flows into incineration in Denmark, to establish recycling systems for window profiles and pipes in the Netherlands or the currently negotiated commitment to reduce PVC flows going to landfills in the UK.

Finally the recovery of the prices for virgin plastics can be expected, following the usual price cycles and thus improving the economic conditions for plastics recycling.

(6) As a consequence of these trends we expect the following development of PVC recycling by 2020 (**„Trend Scenario“**):

- The conditions for the recycling of **pre-consumer wastes** will remain comparatively stable. As a consequence the recycling rate will remain approximately on the present level. This means that the recycled PVC quantities will increase in parallel with the pre-consumer waste arising, reaching **550'000 tons in 2020** and **780'000 tons in 2020**.

- The **recycling of post-consumer wastes** will be improved. It can be expected that the existing recycling systems (for building products especially) will be extended to keep pace with the increasing PVC waste volumes and new recycling systems will be established in the frame of the recycling of electric and electronic products. As a consequence, the recycling rate is expected to increase from less than 3% at present to **8% in 2010** and **9% in 2020**. By 2020 the recycled quantity of PVC post-consumer wastes will increase by a factor of more than 5, reaching **540'000 tons**. Nevertheless, in spite of the improvements the recycling rate will stay on a very low level, thus the contribution of mechanical recycling to PVC waste management will not be improved significantly. One reason is that PVC wastes with comparatively low recycling potentials (short-life consumer and commercial PVC products especially) are expected to increase over-proportionally, compared to wastes with high recycling potentials (building products especially).

- A major part of the increase in PVC post-consumer recycling is due to the **„low-quality recycling“** of PVC wastes from the recycling of electric and electronic scraps, adding to the recycling of cables and packagings. Thus, the „low-quality recycling“ will maintain its dominance, accounting for about **two thirds** of post consumer recycling in 2020.

POTENTIALS FOR IMPROVEMENT

(7) A strategy for further improvement must aim at the **encouragement of those PVC wastes and product groups where mechanical PVC recycling is a favourable waste management option**.

A minimum requirement for mechanical recycling to be favourable is that it provides **environmental advantages**. According to the result of the related assessments carried out in this study, this applies for high-quality PVC recycling only. Thus, **only high-quality recycling should be encouraged by further measures**.

A restriction for some areas of high-quality and low-quality recycling is related with the **toxic compounds** in the PVC recyclates. First, in many PVC applications lead and cadmium have been used as stabilisers which will be dispersed into the different products made of recyclates. Secondly, cable insulation wastes may be contaminated by small concentrations of PCB which was used as an additive in PVC cable insulation in the past. The evaluation of the potential risk associated with these toxic compounds is the subject of controversial discussions. For the future improvement of PVC recycling **two scenarios** have been distinguished, each representing a different point-of-view on this issue:

- In the **„Ecological Risk Minimisation Scenario“** the toxic risks are considered as comparatively high. Therefore a ban on cadmium and lead stabilisers has been assumed here. As a consequence the recycling of some important high-volume products like window frames (stabilised with cadmium and lead), pipes, building profiles, and cables (stabilised with lead) will be phased out, until heavy metal free products will be dominant for the related waste flows (due to the long lifetime of the products this will be not the case before 2020). In addition, stringent standards for PCB will result in a phase-out of the recycling of PVC wastes from post-consumer cables and electronic products. The „high-quality recycling“ of those PVC products not affected by the heavy-metal and PCB issue will be encouraged due to the environmental advantages regarding resource conservation and emission savings. This concerns some household and commercial PVC products especially (sheets, printing films, footwear etc.).

- In the **„Selective Improvements Scenario“** the toxic risks are considered as of limited importance, requiring no prohibitive measures. Therefore, it is assumed that **high-quality recycling will be encouraged** in all relevant areas (building products especially), due to the environmental advantages. Furthermore it is assumed that there will be **no measures in the area of low-quality recycling**. The recycling in the economically profitable areas (PVC wastes from cable and electronic product recycling) and in the legally regulated areas (packaging wastes) will be not affected in this scenario.

The recycling of **pre-consumer wastes** is straightforward already. Therefore, no additional measures have been assumed here. Heavy metals represent no issue for pre-consumer recycling, since in the case of a ban on cadmium and lead the switch to heavy-metal free materials for recycling will happen immediately (in contrast to post-consumer wastes, due to the long lifetime of the products).

(8) As mentioned above there exists already a lot of measures in the EU whose implementation will improve the conditions for PVC recycling. As a consequence, **measures to increase (high quality) PVC recycling** must focus on the further development of the existing recycling systems, broadening their regional scope, and establishing supplementary recycling systems for additional PVC products/wastes, including PVC profiles in construction wastes and some PVC products in household and commercial wastes (especially footwear, printing films and sheets). The major focus must be on **PVC in construction and demolition wastes** where the mechanical recycling potentials are high (both quantitatively and qualitatively) and the recycling activities are limited, partially due to the lack of related regulations.

In the recycling process the **collection** of the wastes represents the major bottleneck regarding costs and achievable recycling rates. To achieve sufficiently high collection rates not only collection systems with a broad regional coverage have to be established, there must be also **financial incentives** for a separate collection. According to the experiences gained with existing recycling systems for PVC and other wastes the financing of the systems should be organised in such a way that the cost charged to the waste owners must be competitive to the fees for landfilling or other waste management options. In many cases this will require a take-back of the PVC wastes free-of-charge, since the additional expenses of the waste owners for separating, storing and transporting the wastes for recycling must be compensated.

(9) **Potential instruments** to further increase PVC recycling range from

- statutory orders or prohibitions,
- over „economic" instruments
- to voluntary agreements.

Possible **statutory regulations** include the **separation of PVC and other plastics** in construction and demolition wastes on construction sites or EU-wide **recycling quota** for the relevant waste streams (construction wastes and specific municipal solid waste fractions like footwear/textiles, PVC printing films or sheets). Another potential measure is the modification of the European landfill directive by inclusion of a definitive **ban on the landfilling of plastics** and other reactive components, following similar national regulations and being also valid for construction and demolition wastes. Finally in the „Proven Environmental Benefits Scenario" a **ban** or stringent concentration standards for recycling materials containing cadmium, lead and PCB can be imposed.

Possible **„economic measures"** are **taxes or levies on landfilling or incineration**. Another possibility is to enforce recycling organisations for construction and demolition wastes similar to those existing for packaging wastes, by **imposing overall recycling goals** and leaving implementation and financing up to industry. There are also „soft" measures for supporting the acceptance of the existing and possible future recycling systems like **information campaigns**.

Finally the related PVC industry can be committed to increase PVC recycling or the recycling of the relevant waste streams respectively by **voluntary agreements**, following the examples of some Member States. Such agreements may be made on the EU level or separately for the individual Member States.

Most measures do not specifically encourage mechanical recycling but PVC recovery in general. Since the costs for mechanical recycling are higher than e.g. for energy recovery in most cases it may be necessary to **„protect" high-quality mechanical recycling**, e.g. by imposing specific recycling quota for mechanical recycling or by additional financial incentives.

(10) The projected **impact** of the improvement measures on the development of **recycled PVC quantities** can be summarised as follows:

- The recycling of **pre-consumer wastes** will not be affected, i.e. the comparatively high recycling rates will be maintained so that the recycled quantities will grow in parallel with the increase in the pre-consumer waste arisings reaching about **800'000 tons in 2020**.

- In the **„Ecological Risk Minimisation Scenario“** the development of the PVC post-consumer recycling remains below the projections for the „Trend Scenario“: In 2020 about **410’000 tons** of PVC will be recycled, as against 540'000 tons in the „Trend Scenario“. The recycling rate will increase, but will not reach a significant level: By 2020 it will not exceed **7%**. However, there will be a major shift in the composition of the recycled quantities compared to the „Trend Scenario“: The recycling of wastes from electric and electronic recycling will be phased-out, the recycling of building products will be restricted to floorings and the recycling of different household and commercial products (sheets, footwear, printing films, etc.) not yet established will play an important role. As a consequence there is a shift to “high quality” recycling, which will contribute with two thirds to the recycled quantities in 2020.

- In the **"Selective-Improvements Scenario"** a significant increase of recycled PVC post-consumer quantities will be achieved compared to the „Trend Scenario“. Due to the encouragement and up-scaling of (“high-quality“) recycling systems for building products (floorings pipes, windows, building profiles), the recycling rate can be increased considerably reaching **18% in 2020** (compared to 3% today). The recycled quantities of PVC post-consumer wastes will reach **1.1 million tons** in 2020. Since the increase will be achieved in „high-quality recycling“ areas the share of “high-quality” recycling will increase to nearly 70%, whilst the contribution of „low-quality“ recycling will be reduced to nearly 30% by 2020.

(11) As a matter of fact, the encouragement of mechanical PVC recycling will result in additional costs. With the exception of pre-consumer wastes and post-consumer wastes from cable and electronic scrap recycling the costs of mechanical recycling will remain higher than the costs for waste disposal (landfilling and incineration).[20]

As a consequence, the mechanical recycling must be “subsidised“, i.e. the additional costs compared to waste disposal must be borne by society, industry or waste owners (depending

20) According to the final draft of the study „Chemical recycling of plastics wasts (PVC and other resin)“ conducted by TNO for DG III the same applies for the **chemical recycling** of PVC and other plastics. The costs given in this study for the chemical recycling of building and construction wastes (about 390 Euro/t) are even higher than the costs of mechanical recycling. The costs given in this study for the chemical recycling of mixed plastics wastes is 500 Euro/t. Although no general cost figures could be developed here it can be stated safely that the costs for the mechanical recycling of these wastes are at least in the same order of magnitude, for some wastes like packagings they are much higher.

on the financing model). These additional costs (i.e. the difference between the total costs for landfilling or incineration and the costs for mechanical recycling including all operations, collection, transportation and treatment) can be estimated very roughly as follows (figures apply for the year 2020 and for all EU Member States):

- **„Trend Scenario“: 90 – 110 million Euro per year,**
- **„Ecological Risk Minimisation Scenario“: 180 – 190 million Euro per year**
- **„Selective Improvements Scenario“: 230 – 290 million Euro per year.**[21]

(12) However, notwithstanding which improvement measures are taken, an important conclusion is that **mechanical recycling is not qualified to contribute significantly to the management of PVC post-consumer wastes in the next decades, reaching at most 18% of total PVC waste arising**. This means that the major part of future PVC waste volumes has to be recovered or disposed of in other ways, including incineration, energy recovery, landfilling and possibly feedstock recycling.

21) This estimation is based upon the projections of the recycled quantities of the major PVC products in the scenarios and the following average cost differences between recycling and landfilling or incineration which are based upon the cost figures given in Chapter 3.3: Flooring 200 – 300 Euro/ton, pipes 100 – 200 Euro/ton, window profiles 100 – 200 Euro/ton, profiles 100 – 200 Euro/ton and other products 500 Euro/ton. The costs for packaging recycling are included as well. The cost of the „Ecological Risk Minimisation Scenario“ does not include lost profits for giving up economic profitable low-quality recycling activities.

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Appendix

Potentials or Hig -quality Recycling

Potential recycling and absorption rates for high-quality mechanical recycling; *shaded = candidates for high-quality recycling (more than 20'000 tons per year in 1998 - 2020)*

PVC product/waste group	**Potential recycling rate (%)**		**Potential absorption rate[a] (%)**
	Pre-consumer wastes	**Post-consumer wastes[b]**	
1. Construction products			
Cables (F)	–	–	5
Flexible films (F)	**80**	–	10
Flooring calandered (F)	**40**	**20-30 (25)**	30
Flooring paste (F)	**40**	–	–
Roofing membranes (F)	–	–	–
Profiles and hoses (F)	**50**	**15-25 (20)**	10-30
PVC wall papers (F)	–	–	–
Air inflated structures, container, marquee (F)	**75**	–	–
Varnishes–coil coating (F)	–	–	–
Pipes (R)	**50**	**70-80 (65)**	35
Window profiles (R)	**75**	**50-60 (55)**	45
Profiles – cable trays (R)	**75**	**30-50 (40)**	40
Other profiles (R)	**55**	**30-50 (40)**	30
Pipe insulation films (R)	**90**	–	30
Sheets (R)	**70**	–	30
2. Packaging products			
Flexible films (F)	**80**	–	–
Cans (F)	–	–	–
Rigid films (R)	**70**	–	–
Bottles (R)	**90**	**30-50 (40)**	–
3. Furniture components			
Flexible films (F)	**35**	–	–
Flexible profiles (F)	**10**	–	–
Rigid films, kitchens (R)	–	–	–
Rigid films, drawers (R)	–	–	–
Other rigid films (R)	**15**	–	5

F = Flexible PVC applications; R = Rigid PVC applications

a) related to post-consumer wastes

b) in brackets = chosen rates

PVC product/waste group	Potential recycling rate (%)		Potential absorption rate[a)] (%)
	Pre-consumer wastes	Post-consumer wastes[b)]	
4. Other consumer and commercial products			
Bags, luggage, cushions (F)	**25**	5-15 (10)	–
Office supply, books, photo articles (F)	**80**	5-15 (10)	5
Camping, leisure, toys (F)	**30**	10-20 (15)	10
Misc. plasticised films (F)	**60**	10-20 (15)	10
Garden hoses (F)	**90**	–	35
Drinking hoses (F)	**70**	–	–
Other industrial hoses (F)	**70**	–	20
Other flexible profiles (F)	**55**	5-15 (10)	15
Artificial leather (F)	–	–	–
Conveyor belts (F)	–	–	–
Miscellaneous coatings (F)	–	–	–
Rotational mouldings (F)	–	–	–
Slush mouldings (F)	–	–	–
Misc. organo-/plastisols (F)	–	–	–
Shoes, soles (F)	**90**	**10-30 (20)**	35
Miscellaneous (F)	**90**	**5-15 (10)**	–
Office supply (R)	**80**	30-40 (35)	25
Printing films (R)	**80**	**30-40 (35)**	–
Credit cards (R)	–	–	–
Computer disks (R)	**80**	–	–
Other techn. applications (R)	**90**	20	30
Sheets, chemical equipm. (R)	**80**	**30-40 (35)**	30
Miscell. sheet products (R)	**70**	**20-40 (30)**	30
Miscell. rigid profiles (R)	**75**	**10-20 (15)**	10
Vinyl records (R)	**65**	–	–
Other rigid products (R)	**90**	**10-20 (15)**	10
5. Electric/electronics			
Cables (F)	**15**	–	–
Adhesive tapes (F)	**80**	–	–
Flex. profiles, hoses (F)	**40**	–	–
Inject. moulding parts (F)	**90**	–	10
Rigid profiles	**75**	10-20 (15)	10

F = Flexible PVC applications; R = Rigid PVC applications

a) related to post-consumer wastes

b) in brackets = chosen rates

PVC product/waste group	Potential recycling rate (%)		Potential absorption rate[a)] (%)
	Pre-consumer wastes	**Post-consumer wastes[b)]**	
6. Automotive			
Cars cables (F)	**50**	–	–
Instrument panels and other films (F)	**25**	–	10
Cabletapes and cable-binders (F)	**35**	–	10
Hoses, flexible profiles (F)	**85**	–	10
Foamed films/artificial leather (F)	**15**	–	–
Tarpaulins for lorries (F)	**35**	–	–
Underfloor protection (F)	–	–	–
Others, inj. moulding (F)	**90**	–	10
Rigid profiles (R)	**75**	10-20 (15)	–
Battery separators (R)	**85**	40-60 (50)	–
7. Other Products			
Agricultural films (F)	**65**	–	–
Medical products (F):	**75**	–	–

F = Flexible PVC applications; R = Rigid PVC applications

a) related to post-consumer wastes

b) in brackets = chosen rates

Potentials or o -quality Recycling

Potential recycling and absorption rates for low-quality mechanical recycling

	Potential recycling rate (%)	
PVC product/waste group	**Pre-consumer wastes**	**Post-consumer wastes[a)]**
1. Construction products		
Cables (F)	60	70-90 (80)
Flexible films (F)	–	–
Flooring calandered (F)	55	–
Flooring paste (F)	55	–
Roofing membranes (F)	–	–
Profiles and hoses (F)	45	–
PVC wall papers (F)	–	–
Air inflated structures, container, marquee (F)	–	–
Varnishes–coil coating (F)	–	–
Pipes (R)	45	–
Window profiles (R)	20	–
Profiles – cable trays (R)	40	–
Other profiles (R)	40	–
Pipe insulation films (R)	–	–
Sheets (R)	–	–
2. Packaging products		
Flexible films (F)	–	15-25 (20)
Cans (F)	–	–
Rigid films (R)	25	15-25 (20)
Bottles (R)	–	–
3. Furniture components		
Flexible films (F)	60	–
Flexible profiles (F)	60	–
Rigid films, kitchens (R)	60	–
Rigid films, drawers (R)	60	–
Other rigid films (R)	60	–

F = Flexible PVC applications; R = Rigid PVC applications

a) in brackets = chosen rates

PVC product/waste group	Potential recycling rate (%)	
	Pre-consumer wastes	Post-consumer wastes[a)]
4. Other consumer and commercial products		
Bags, luggage, cushions (F)	60	–
Office supply, books, photo articles (F)	15	–
Camping, leisure, toys (F)	60	–
Misc. plasticised films (F)	-	–
Garden hoses (F)	-	10-20 (15)
Drinking hoses (F)	-	20-30 (25)
Other industrial hoses (F)	-	20-30 (25)
Other flexible profiles (F)	-	–
Artificial leather (F)	90	–
Conveyor belts (F)	–	–
Miscellaneous coatings (F)	–	–
Rotational mouldings (F)	–	–
Slush mouldings (F)	–	–
Misc. organo-/plastisols (F)	–	–
Shoes, soles (F)	–	–
Miscellaneous (F)	–	–
Office supply (R)	–	10-20 (15)
Printing films (R)	–	10-20 (15)
Credit cards (R)	90	–
Computer disks (R)	–	–
Other techn. applications (R)	–	10-20 (15)
Sheets, chemical equipm. (R)	15	10-20 (15)
Miscell. sheet products (R)	–	–
Miscell. rigid profiles (R)	–	–
Vinyl records (R)	–	–
Other rigid products (R)	–	–
5. Electric/electronics		
Cables (F)	70	30-50 (40)
Adhesive tapes (F)	15	30-50 (40)
Flex. profiles, hoses (F)	50	30-50 (40)
Inject. moulding parts (F)	–	30-50 (40)
Rigid profiles	20	30-50 (40)

F = Flexible PVC applications; R = Rigid PVC applications

a) in brackets = chosen rates

PVC product/waste group	Potential recycling rate (%)	
	Pre-consumer wastes	Post-consumer wastes[a)]
6. Automotive		
Cars cables (F)	60	–
Instrument panels and other films (F)	65	–
Cabletapes and cable-binders (F)	60	–
Hoses, flexible profiles (F)	–	–
Foamed films/artificial leather (F)	75	–
Tarpaulins for lorries (F)	60	–
Underfloor protection (F)	90	–
Others, inj. moulding (F)	–	–
Rigid profiles (R)	–	–
Battery separators (R)	–	–
7. Other Products		
Agricultural films (F)	30	–
Medical products (F):	–	–

F = Flexible PVC applications; R = Rigid PVC applications

a) in brackets = chosen rates

Questionnaire

Assessment of mechanical PVC recycling in the EU

Institution/company:

Address:

Contact person:

Phone:

Fax:

E-mail:

In case of questions and remarks please contact:

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1. National PVC waste quantities

Please include the following figures on the present national quantities of PVC wastes:

Question	Answer
a.) Present total quantity of PVC wastes (tons/year) by product group[a)]:	
b.) Present quantity of PVC wastes recycled mechanically (tons/year) by product group [a)]:	
c.) Forecast of total quantity of PVC wastes: • reference year • tons/year	
d.) Forecast of quantity of PVC wastes recycled mechanically: • reference year • tons/year	

a) Please give the figure for total PVC waste quantities and the quantities for each PVC product group available (e.g. pipes, window frames, profiles, cables, etc.)

2. Legal and institutional frame

Please include information on existing regulations affecting recycling

Question	Answer
a.) Which national/regional measures exist to promote PVC recycling in general (e.g. legislation, waste action plans, voluntary agreements)?	
b.) Which regulations/agreements exist to enforce/promote recycling of products containing PVC (esp.: construction materials, packagings, electric/electronics, cars)	
c.) Are there legal limits to the landfilling of plastics/organic materials? (from which year on is this regulation valid?)	
d.) Other important regulations/agreements affecting PVC recycling in future?	

3. Description of existing recycling sytems

a) Recycle astes (in ut)

Question	Answer
a.) Origin of the PVC wastes: • Production wastes[a)] (tons/year) • Post-consumer Wastes (tons/year)	
b.) Quality of the PVC wastes: • mixed plastics wastes or • PVC fractions out of sorting plants • pure PVC fraction from separate	
c.) Which quantities of PVC production wastes are recycled per year (tons/year), distinguished by product groups[b)]:	
d.) Which quantities of PVC post-consumer wastes are recycled per year (tons/year), distinguished by product groups [b)]:	

a) this includes wastes from the production of PVC products as well as wastes from the further use/ processing/installation of the products, e.g. cut-offs from flooring
b) Please indicate the input quantities (=collected quantities) for each PVC product group, e.g. pipes, window frames, profiles, cables, etc.

) rganisation an inancing o t e recycling system

Question	Answer
a.) What are the main tasks of the recycling organisation?	
b.) Which steps of the material flow is the recycling organisation occupied with? • recycling/treatment process • sorting • collection • transports	
c.) How is the recycling system being financed? (e.g. fee on product price, fee on PVC post-consumer waste, public or private subsidies; etc.)	

c) Recycling material (out ut)

Question	Answer
a.) Qualities of the recycling materials (recyclates): For which purposes can the recyclates be used? • equivalent to virgin PVC • production of PVC products with multilayer and similar technologies • production of other products	
b.) In which productions is the recycling material being used and in which quanti-ties (tons/year)?	

) Costs

Question	Answer
a.) Overall costs (EURO per ton) including all operations from collection to marketing of the recyclates (distinguished by waste type/product group)[a]: • per ton of PVC waste collected • per ton of PVC recyclate produced	
b.) Break down of the costs distinguished by waste type/product group[a] according to the major operations: • collection costs (EURO/ton) • sorting costs (EURO/ton) • recycling/processing (EURO/ton) • credits (proceeds) for the recyclates	
c.) Overall costs (EURO/ton) for landfilling and incineration of the relevant wastes (including collection and transport)	
d.) Expectation on the future development of PVC recycling costs	

a) Please give a figure for each relevant PVC product group being recycled

e) Collection

Question	Answer
a.) Collection (distinguished by waste type/product group)[a]: • separate collection of the PVC wastes (yes/no) • collection of PVC in mixed waste fractions with subsequent sorting • collection of PVC in mixed waste fractions and recyling in mixed plastics (without sorting out PVC)	
b.) Extension of the service [a]: • pick-up system at the waste producers or • delivery by the waste producer to	
c.) Regional coverage: • Size of the region from which PVC wastes are collected (e.g. number of inhabitants, geographical area) • number of collection points	

a) Please give a figure for each relevant PVC product group being recycled

) orting

Question	Answer
a.) Methods for sorting • mechanically • by hand	
b.) Quality of the output material: Is a pure PVC fraction being sorted out? If no: What is the PVC-content of the mixed plastics fractions being sorted out for mechanical recycling (weight-%)?	
c.) Plant size: • Capacities (tons/year waste input) of the sorting plants? • Average diameter (km) of the region from which wastes are transported to the sorting plant	

a) Please give a figure for each relevant PVC product group being recycled, e.g. pipes, window frames, profiles, cables, etc.

g) Recycling/treatment rocess

Question	Answer
a.) Description of the technology: What are the major unit operations of the recycling/treatment process (if available please include a flow chart of the process)?	
b.) Technical parameters: • plant capacity (ton/year) • input of wastes (ton/year) • output of PVC recyclates • output of other recycling material	
c.) Environmental parameters: • Production of non-hazardous wastes to landfilling or incineration (tons/year) • Production of hazardous wastes (tons/year) • Electricity consumption (kWh per ton of waste input) • Fuel consumption (MJ per ton of waste input) • Waste water (m^3 per ton of waste input) • Major air emissions (kg per per ton of waste input) • Major water emissions (e.g. CSB per ton of waste input) • special safety precautions	

imits to mec anical P C recycling

Question	Answer
a.) What are the major limits to an increase in PVC recycling[a)]? • economic limits (e.g. costs) • technical limits (e.g. material specifications) Which PVC products are mainly affected by these limits?	
b.) What are the major measures to improve mechanical PVC recycling?	

a) for each relevant PVC product group, e.g. pipes, window frames, profiles, cables, etc.